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EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS

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EXPERIMENT PROGRAM

FOR

EXTENDED EARTH ORBITAL MISSIONS

REVISION NO. 1

To The

"Experiment Program For Manned Orbital Workshops"

Dated August 14, 1968

September 1, 1969

PAYLOADS DIRECTORATE
ADVANCED MANNED MISSIONS PROGRAM
OFFICE OF MANNED SPACE FLIGHT

PREFACE TO FIRST REVISION

The material contained in the two volumes comprising the experiment program for manned earth orbital missions represents the results of planning within NASA for the experiments, payloads and research facilities to be conducted on earth orbital missions of the 1970's and early 1980's. As such it is a compendium of program office views with respect to anticipated needs and requirements for experiments to be considered for flight in that time period.

The first revision reflects a very considerable effort extending the draft version of the "Experiment Program for Manned Orbital Workshops" (Yellow Book), dated August 14, 1968. Requirement for this revision was based upon a need to review, reexamine and extend the original Yellow Book material which included the disciplines of Astronomy, Earth Applications, Space Biology and Space Physics plus a need for extension of the experiment program to embrace the disciplines of Aerospace Medicine, Advanced Technology and Materials Processing/Space Manufacturing. These changes, revisions and additions have now been accomplished, to an acceptable though incomplete degree in some cases, and are reflected in these documents.

The original Yellow Book was used as the basis for a number of advance planning activities; in particular the PSG Working Groups and as source material for space station candidate experiment programs. This and similar uses are expected to continue in the future. In addition, a continuing requirement exists to maintain in one document, as complete a set of proposed experiments as possible, together with the description and requirements for these experiments, for use by the program offices and field centers in future extended earth orbital planning and design effort.

Preparation of this document, as with the predecessor document, was accomplished with and through the appropriate program offices of NASA. Thus, the Office of Advanced Research and Technology and the Office of Space Science and Applications have made important and valuable contributions to this work, as well as the MSF field centers. This coordination and review has accomplished several important aims. First, the joint working relationship with the program offices in the definition and description of the experiment program has resulted in a common understanding of the experiment goals and objectives in each discipline and a common language in referring to them. Secondly, the effort required to develop the material has led to an improved working relationship and understanding between offices. Lastly and probably most importantly, in most of the disciplines, it has resulted in a firm understanding of the experiments to be flown and a commitment to work toward their timely flight.

This revision also reflects some important differences from its predecessor. First, the disciplines of Aerospace Medicine, Materials Processing and Manufacturing in Space, Engineering and Operations and Advanced Technology are now included. They were not contained in the August 14, 1968 Yellow Book. Secondly, the Science and Applications portion containing the Space Physics, Astronomy, Earth Surveys and Space Biology disciplines have been very extensively reworked. This has resulted in a number of changes and deletions in various sections which the user will discover, leading to an improved and expanded technical detail. Some sections, noteably Aerospace Medicine and Earth Surveys are subject to continuous scrutiny and revision; for this reason these sections should be considered as draft/source material only, with the final Yellow Book quality material due out as a replacement in the near future.

The material contained in the extended earth orbital experiment program in this document is a product of the NASA in-house Integrated Payload Planning Activity. This planning activity is a joint effort among the Office of Manned Space Flight, Bellcomm, the Office of Space Science and Applications and the Office of Advanced Research and Technology and is supported by planning groups at MSC, MSFC, and LRC. Though many individuals are involved in this joint payload planning activity, some have participated more directly in the preparation of this document. These include: P.G. Thome, OSSA; D. Novik, OART; R.W. Dunning, OART; A.T. Mattson, LaRC; W.N. Gardner, LaRC; W.T. Carey, MSFC; J.O. Hilchey, MSFC; D.E. Hagge, MSC and R.E. Hergert, MSC.

Though this document is a product of the Payloads Office and the responsibility for its contents must be acknowledged, the efforts of these individuals are much appreciated.

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ABSTRACT

Assuming completion of the Saturn AAP workshop experiments program, an experiments payloads plan has been developed for the Space Station of the mid-seventies. Based upon the objectives of the space station program and their relative importance, three experiments program options have been developed.

Each option was generated to accommodate varying levels of experiment accomplishments and assumed different levels of funding availability. Specifically, the hard core option will only provide information on the physical well-being of the astronaut and limited data regarding his ability to perform useful functions in space. The second option will, in addition, provide limited scientific data in the areas of solar astronomy and earth applications while providing additional information on man's capability to perform useful functions in support of scientific data gatherings. The third option satisfies most of the objectives of the intermediate space station program. This option will provide for exploratory experimental efforts in a number of scientific disciplines and will allow examination of man's usefulness in support of these scientific investigations, and, significantly, will provide conclusions regarding man's role in future exploration and exploitation of space.

The experiment program plan was developed to provide maximum flexibility from the standpoint of operations and funding. It allows selection of individual experiment packages or modules to accomplish a specific entity of the overall experiment program. Such selection may be dictated by considerations of logistics or development.

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INTRODUCTION

During the past decade, space has provided a new frontier for exploration and a renewed appeal to man's adventuring spirit. Outstanding space accomplishments ranging from close-up observations of Mars by automated Mariner spacecraft to the manned lunar landing of the Apollo program have been achieved. It is now essential that space flight continue to provide economic benefits, enhancement of scientific knowledge, industrial applications and security to the nation if a major space effort is to continue. While recognizing that experiment activities alone are not sufficient justification for manned space flight, it is however, considered essential that a substantial exploratory experiment effort be conducted during the seventies to help focus direction for future manned space activities.

In consonance with this philosophy, experiments conducted during the seventies should help insure maximum scientific returns consistent with the state-of-the-art capability, provide a logical base upon which follow-on programs can be developed, contribute to a fundamental understanding of what man's proper role in space should be and advance the technology base for the development of future operational and experiment systems.

It is the purpose of this document to define a Manned Space Flight experiment program that could be conducted in earth orbital space stations during the mid-seventies and to form a basis for potential follow-on programs. These proposed programs conform to the recognized goals for orbital space station research of this time period. These goals are:

(1) To extend the present knowledge of the long term bio-medical and behavioral characteristics of man in space. Specifically, to determine and evaluate man's physiological responses and aptitudes in space, and his post-mission adaptation to the terrestrial environment, through a series of progressively longer missions, including resolution of need for artificial gravity and the increments by which mission duration can be increased.

(2) To continue the development of system and technology required for long duration flight. Specifically, to develop techniques for increasing systems life for long duration habitability, and for long duration mission control; to investigate and develop techniques for inflight test and qualification of advanced subsystems.

(3) To investigate the use of manned systems for the efficient conduct of scientific, technological, and space applications endeavors. Specifically, to develop and evaluate efficient techniques utilizing man for sensor operation, discrimination, data selection and evaluation, manual control, maintenance and repair, assembly and set-up, and mobility involved in various operations.

Based on material generated by current working groups in the various experiment disciplines and by a recent work session on manned space flight experiment requirements, a manned space flight experiment program for the mid-seventies has been developed which is in accord with the goals enunciated above. Details of this experiment program and of the experiment activities planned in the various disciplines are presented in the following sections.

EXPERIMENT PROGRAM OPTIONS FOR MANNED ORBITAL WORKSHOPS

Three experiment program options have been developed for the Intermediate Orbital Workshop in the mid-seventies. These options were developed under the assumption that the experiment activities currently planned for the Saturn AAP Workshop in the 1970-71 time period will precede each program option. A brief description of the Saturn AAP Workshop experiment program and flight schedule is given below.

A. SATURN AAP WORKSHOP EXPERIMENT PROGRAM

The Saturn AAP Workshop activities represent an exploratory effort for the eventual achievement of long duration space station operations and experimentation. Primary experiment emphasis in the Saturn AAP Workshop will be in the biomedical area and will include evaluation of the physiological effects of long duration and zero gravity. Quantitative measurement will be taken of cardiovascular functioning, blood changes, bone density, nutrition, neurological effects, balance mecahnism, pulmonary functioning, metabolism and physical conditioning. In the area of man-machine evaluations a time and motion study of crew task performances will be made during setup and operation of the workshop. An evaluation will be made of workshop provisions for habitability, EVA operations, and work station performances. The ATM will be utilized to conduct exploratory observations in solar astronomy. It represents the first operation of a high resolution telescope in space for observing solar activity and as such

constitutes the first flight testing of equipment and operating concepts for follow-on manned astronomical observatories. Simple space biology carry-on experiments will be conducted. In the area of space physics, preliminary investigations of near earth environments will be carried out. No experiment commitments have been made in the earth resources area. However, a number of experiments have been considered and are described in the appendix under Earth Applications - Earth Resources (FPE I). In addition, a preliminary investigation of space manufacturing processes has been considered for inclusion in the Saturn AAP Workshop.

B. SPACE STATION EXPERIMENT PROGRAM

The three manned space flight experiment program options descrived in this section represent three typical levels of experiment activity and as such reflect different levels of funding requirements. The options have been developed from material given in References 1 and 2, from material generated by the various disciplinary working groups and by MT-sponsored three-day work sessions on manned space flight experiment requirements as well as from information made available by the various program offices.

An outline of the three experiment options is presented below together with typical launch dates and runout costs of the various elements comprising each program option.

1. Hard Core Program: This program option is designed to obtain information about man's capability to live and function in earth orbit. It provides the minimum necessary experiment data to verify man's capa-

bility to live in zero gravity and to understand his capability to function in a useful capacity. It consists of the following activities:

a. Biomedical Experiments (Integrated Medical Behavioral Laboratory Measuring System (IMBLMS) and Ancillary Experiments)

b. Man-machine Evaluations

2. Medium Experiment Program: This program option is a slightly more ambitious effort to obtain information (1) about man's capability to live and function in earth orbital and (2) about man's ability to perform useful activities in orbit through conduct of a minimum experiments effort in astronomy and earth applications. This option includes:

a. Biomedical Experiments (IMBLMS and Ancillary Experiments)

b. Man-machine Evaluations

c. Astronomy Survey Experiments

d. Earth Resources Experiments

e. ATM Astronomy (High Energy, Solar, Stellar)

f. Space Physics Experiments

g. Space Biology Experiments

h. Space Manufacturing Processes

At the present time a balanced experiment program represents the desired approach toward an experiment program for large space stations.

INTERMEDIATE ORBITAL WORKSHOP

LAUNCH DATES FOR EXPERIMENT PROGRAM ELEMENTS

CY	72	73	74	75	76	77
Biomedical						
IMBLMS and Ancillary Experiments			X	X		
Engineering/Operations						
Man-Machine Evaluations			X	X		
Space Manufacturing			X			X
Astronomy						
Survey			X			
ATM Hi-Energy			X			
Solar				X		
Stellar					X	
Earth Resources			X			X
Space Physics						
Air Lock Experiments			X			
Hi-Energy Cosmic Ray					X	
Subsatellite						X
Space Biology						
Bio E (Plants)			X			
Bio D (Small Vertebrates)				X		

DISCIPLINARY OBJECTIVES AND ACTIVITIES

The details of the manned earth orbital experiment activities planned in the various disciplines as presented in this document are based on material generated by the Integrated Payload Planning Activity on manned space flight experiment requirements. The work of this group has led to the development of the material included in the two volumes, Science and Applications and Engineering and Technology. The material comprising the Science and Applications Section includes the disciplines of astronomy, earth surveys, bioscience and space physics and is largely up-dated material included in the earlier version dated August 14, 19[illegible]. [illegible]e material comprising the Engineering and Technology sectio[illegible] is ne[illegible] and has been developed in concert with the disciplinary working groups and/or program offices.

A. AEROSPACE MEDICINE

Objectives: To determine the effects of the space environment on man for increasing durations up to two years, to develop real time indices of functional impairment and to develop a supportive environment and conditioning procedures to offset any ill effects of space flight and reentry.

Background: For the present this area must receive first priority over all others each time the duration of a mission is extended beyond the previous record (14 days at present). A complete set of tests of man's bodily status and functions will be carried out at regular intervals using an Integrated Medical Behavorial Laboratory

Measuring System (IMBIMS). A series of conditioning exercises to offset the effects of zero gravity must be tested and evaluated. An optimum spacecraft atmosphere must be selected. Habitability conditions must be improved for both living and working. As experience accumulates, the testing time required during the early stages of a prolonged mission can be reduced. Data must be accumulated rapidly during the next few missions to enable an early decision as to whether artificial gravity will be desirable in future spacecraft designs. Adquate volume must be provided for living and exercise space per man, and more will be required with longer missions.

Experiment Description: The basic experiment flight hardware required to satisfy the biomedical program in the Intermediate Workshop era consists of the IMBIMS facility, an independently configured medical laboratory suited for integration into a workshop vehicle. IMBIMS provides an on-board unit for obtaining basic medical/behavioral data in the zero gravity environment. These include data in such areas as alveolar-arterial oxygen gradient, regional blood flow, venous pressure, cardiac output, on-board hematological measurements, breath-by-breath measurements, oxygen consumption and carbondioxide production, bone densitometry, etc. IMBIMS currently will support approximately 173 individual measurements of body functional areas necessary to effectively evaluate man's physiological status in orbit.

A data management subsystem is being incorporated into the basic package design to accommodate data outputs generated by the system. However, this subsystem will require a tie-in into the basic spacecraft transmission system to relay on-board data to the ground.

A complement set of provocative test apparatus (lower body negative pressure, pressure cuffs, stimuli generators and simulators) also are required to support the basic IMBIMS facility and provide the necessary stimuli and support equipment needed to complete the medical laboratory.

In addition, it is required to provide for definition of bio-medical experiments to be conducted with the IMBIMS facility as well as experiments designed to update measuring instruments for the IMBIMS.

Estimated cost	(IMBIMS)	$40M	Weight:	800 lbs.
	(Ancillary experiments)	10M	Volume:	60 cuft
Availability	CY '73		Power Requirements:	1/2 KW

B. ASTRONOMY

Objectives: To operate large, high-performance, high reliability telescopes and survey instruments above the atmosphere to study radiation from the sun, planets, and stars throughout the spectral regions from high energy gamma rays to long wavelength radio waves.

Background: The advantages of operating in space to avoid the spectral masking and geometric resolution limitations imposed by the atmosphere, together with the importance of astronomy to our understanding of the universe and to our future space program, make this field a high priority space effort. Manned systems can offer important assistance in providing large, high-reliability, long duration versatile telescope systems in space. Hence, a well planned program in which one or more telescope systems is proved on each manned space station seems warranted.

In addition to providing advanced scientific data in astronomy, this program would be designed to evaluate technological concepts leading toward development of more advanced astronomy observatories. Further, it should provide a test bed for careful analysis of man's capability to operate and functionally sypport major experiment elements in earth orbit. Development and demonstration of techniques for more precise stabilization systems could be evaluated. Investigations of various modes of operation (hard-docked vs. free flying) could be assessed to guide development of more advanced space observatories. This device then represents a link in the progressive buildup to a capability for operating a large manned orbiting observatory in the 80's with a telescope of the 120" class.

The manned experimental activities in astronomy would consist of two distinct categories: one would entail observations of selected targets in detail, using large telescope systems in conjunction with ATM; the other would entail a broad range search to locate celestial objects of scientific interest.

Experiment Description: The experiment packages for astronomy consist of three ATM astronomy packages (high-energy, solar, UV stellar) and two survey packages (UV, gamma- and X-ray).

1. ATM High-Energy Package - This experiment package will contain a grazing incidence imaging X-ray telescope and will be capable

of providing spatial and spectral resolution of point and extended galactic X-ray objects, as well as polarization data in the spectral range from about 2 to 200 Å. Specific instruments to be used with the imaging X-ray telescope are a field-imaging spectrometer, a curved crystal X-ray spectrometer, and an X-ray polarimeter.

System requirements are similar to those for ATM-A. Moreover, 360° roll pointing and 1 arc min roll stability is required. Film return capability of about 250 lbs. every two months should be provided. Orbital inclination and altitude are not critical.

Estimated cost (Instruments)	\$ 33M	Weight (Instruments)	1750 lbs.
(ATM Carrier)	125M		
Availability	CY 74	Power requirement:	$\frac{1}{2}$ kw.

2. <u>ATM Solar Package</u> - This experiment package represents a logical extension in the field of solar astronomy from the ATM-A effort for continued observation of solar phenomena in the UV and X-ray range using instruments with minor refinements in spatial and spectral resolution and in pointing and scanning modes. The capability to provide high resolution motion pictures of the sun in white light, mean UV and H also would be included.

Specific experiments would use such instruments as: 1) UV spectroheliograph and spectrograph as initially proposed by NRL, 2) UV spectroheliometer and UV spectrometer from Harvard Observatory, 3) Photoheliograph for high resolution motion pictures of sun in visible, UV, and Hα range, and 4) X-ray telescope.

Pointing systems requirements are similar to those for ATM-A. However, systems design and packaging arrangements should be made more suitable for maintenance. Film return capability of about 1000 lbs. per quarter should be provided. Orbital inclinations of 28° to 50° at altitudes from 200-300 N Mi will be satisfactory.

Estimated Cost (Instruments)	$ 65M	Weight (Instruments)	5500 lbs.
(ATM Carrier)	100M		
Availability	CY 74	Power Requirement	$\frac{1}{4}$ kw

3. <u>ATM UV Stellar Package</u> - This experiment package contains a large aperture non-defraction limited UV telescope, which is a modification of the OAO Goddard Instrument Package. It is a one meter aperture system capable of conducting stellar observations of extended and point sources, using spectrographic, photometric and imaging techniques. Modification to the OAO instrument include designing critical subsystems for maintenance and servicing by the astronaut and adding the imagery and spectrographic capability taking advantage of man's presence for changing film. The telescope field of view is approximately 20 arc minutes and will require a 3-axis gimbal mount with a pointing accuracy of about ± 1 arc minute. Orbital inclinations of 28° - 50° at altitudes of 200-300 N Mi are satisfactory.

Estimated Cost (Instruments)	$ 25M	Weight(Instruments)	2500 lbs.
(ATM Carrier)	125M		
Availability	CY 74	Power Requirements	$\frac{1}{4}$ kw

4. <u>Astronomy Survey Packages</u> - The survey class of experiments involve a variety of high energy observations in the gamma-ray, X-ray and UV regions of the spectrum. They can be combined into two experiment packages:

a. The UV Survey package would include two 6" UV cameras with selected filters, an all reflective UV spectrograph and a Schmidt type image converter spectrometer. This set provide UV imagery of star fields and emission regions from 1800-3000 Å and spectral photometric data in the 900-1800 Å regime.

This package (total weight about 600 lbs.) could be integrated into the OWS for launch with the platform (providing $\pm$ 30 arc sec stability for 15 min exposures) attached to a swing-out boom for operation. Power, (24 watts ave., 160 watts peak) telemetry (house-keeping only) and a base stability of 10 arc min will be provided by the OWS. Film return capability of about 32 lbs. every two months will be required.

Estimated Cost	$4.8M	Weight	600 lbs.
Availability	Dec. '71	Power Requirements	160 w

b. <u>The High Energy Survey Package</u> would serve three sets of experiments, one X-ray and two gamma-rays, that have undergone extensive definition for the past several years and consequently can be developed for flight without technological delays. The X-ray experiment is a large array of proportional counters for surveying the entire celestial sphere, and would be operated in a scan mode. The gamma-ray detectors are scintillation counters and could be mounted on a common orientation system as they have similar desired targets and viewing times.

The base stability of 10 arc min of the orbital workshop would be adequate for all of these experiments. The total weight,

including all experiments and pointing mechanisms, would be 4,850 lbs, with a power demand of 250 watts on the OWS. The scientific data rate is 1.7 K bits/sec. No film would be required.

Estimated Cost	$3.1 M	Weight	4850 lbs.
Availability	June 72	Power Requirements	250 w

C. EARTH APPLICATIONS

Objectives: To provide manned support in orbit for early development and refinement of new sensing techniques; for inflight checkout and calibration of flight instruments; and for simultaneous employment of several sensors to acquire data for comparison of various sensing techniques.

To determine if man can play a useful role as an observer, in the selection of special targets of opportunity, or as an onboard data compactor.

Background: This field includes remote monitoring of surface and atmospheric features from manned spacecraft, covering agriculture, forestry, hydrology, oceanography, geodesy, geology, and meteorology. The initial space applications program on manned vehicles is intended primarily to contribute significantly to the refinement of an operational earth applications program through flight testing of a limited number of advanced precursor experiment systems to provide desired baseline data for design of more advanced operations systems.

Experiment Description: A typical mix of instruments for an Earth Applications package in the mid-seventies time frame might consist of the following:

A metric camera for ground mapping
A camera system for multispectral photography
2-3 vertical profile radiometers (IR and Microwave) to provide comparison of different techniques for sensing atmospheric parameters
2-3 IR and Microwave imagers for sensing surface features in these wavelengths of electromagnetic spectrum

The Earth Applications payloads have a special requirement for a high inclination orbit--preferably 50° or more--to overfly the many calibrated ground truth sites in the United States. The meteorological experiments must overfly regions having strong air mass contrasts and a wide range of weather patterns. A low altitude--below 200 N Mi--would be desirable for high resolution in some applications. Also, the Earth Applications instruments must be mounted on an earth-looking platform, one axis of which is always perpendicular to the spacecraft velocity vector for image motion compensation and for radar sweep scans. Pointing accuracies of approximately $\frac{1}{2}^{\circ}$ about all three principal axes with rates less than $.03^{\circ}$/sec are required during operation. Provisions for return of 200-300 lbs. of film during resupply intervals is needed.

It is intended that these instruments be developed as a package capable of being included in the space station program as an independent entity. A display and control console also is needed in the space station to allow for crew monitoring and control of the instrument package. Although a carrier has not been defined, one of the type proposed for the AAP-A package should be representative of the kind of carrier needed. Initial estimates approximate the weight of this vehicle to be 5000 lbs.

Estimated Cost	$30M	Weight (Instruments)	800 lbs.
		(Carrier)	5000 lbs.
		Volume	60 cu. ft.
Availability	CY 74	Power Requirements	½ kw

D. SPACE BIOLOGY

Objectives: To study significant biological effects peculiar to the space environment (low gravity, absence of daily cycle and radiation levels), and to develop techniques to apply to later exobiology investigations.

Background: With the increasing capabilities of the manned space station and the increased experience and know-how gained from unmanned automated space biology experimentation, it is expected that there will be greater need and use of scientist astronauts in space biology experimentation.

The experiments planned for the Saturn IB workshop will be largely automated, but will also begin to test man's ability to perform single laboratory tasks such as verifying the integrity of living systems in flight, recording physiological variables and focusing a microscope. Experiments planned for the Intermediate Workshop will involve more elaborate measurements and manipulative skills. Some of them may also provide for tandem automated and astronaut-conducted experiments to allow comparison and evaluation of the effectiveness of the astronaut.

Experiment Description: The experiments earmarked for the manned program can be organized into five functional elements. A functional element may be a package or console containing modularized experiments or it may consist of several consoles thus permitting the

distribution of a program element to several locations within a space station or even to different flights.

Data storage, processing and telemetry for most of the elements will be incorporated into the basic workshop. Thermal control, humidity control, environmental gases, water and other utilities required, in the main, will be obtained from the basic workshop.

The following experiment packages are listed for possible inclusion in planning a space biology program:

	Weight	Volume	Power Reqmt.	Estimated Cost	Availability
Bio A (Primates)	10,700 lbs.	1000 cu.ft.	3.1 kw	$259M	1974-75
Bio C (Microbiology)	140 lbs.	15 cu.ft.	300 w	12.9M	1974-75
Bio D (Small Vertebrates)	200 lbs.	12 cu.ft	200 w	13.3M	1975
Bio E (Plants)	80 lbs.	13 cu.ft.	700 w	12.8M	1973-74
Bio F (Invertebrates)	150 lbs.	5 cu.ft.	200 w	9.3M	1974-75

E. SPACE PHYSICS

Objectives: To study the space environment and its effect in near orbit and to investigate the astrophysical aspects of cosmic radiation.

Background: In the area of space physics, several experiment categories have been identified as requiring astronaut participation. These include experiments which require a small airlock for instrument exposure and retrieval, and experiments in which the sensors are carried in a small satellite detached from the spacecraft. In the area of cosmic ray investigations, the heavy payloads and long data

collection time necessitated by the low fluxes involved make the large manned vehicles the most appropriate means for carrying out these investigations.

The airlock experiments will include measurement of the space environment in the immediate vicinity of the spacecraft and its effect on the performance of optical instruments and on exposed materials. Since it is not possible to duplicate the ionospheric plasma in a laboratory, the opportunity afforded by a space laboratory to investigate it is unique. By means of instruments placed on a small satellite, which can be positioned at will in the vicinity of the space station, measurements of the characteristics of the plasma in the spacecraft wake can be made.

Experiment Description:

1. Airlock Experiments - A group of small individual instruments carried internally in the workshop and utilizing a small scientific airlock for exposure. This group of experiments includes spacecraft debris, contamination and related optical experiments. Although a number of these are scheduled for the wet workshop program it is considered appropriate to continue these investigations into the intermediate workshop.

Estimated Cost	\$4.0M	Weight	200 lbs.
Availability	CY 72-73		

2. High Energy Cosmic Ray Experiments - Cosmic ray investigations for the intermediate workshop are divided into two completely separate techniques which involved studying different aspects of the problem:

a. A high energy cosmic ray experiment using scintillators, proportional counters, Cerenkov counters, spark chambers and ionization calorimeters should provide electron and nucleon energy and charge measurements in the range Z = 1 to 30 and energy range 10^{10} to 10^{15} eV.

b. A very large area (10 to 20 m^2) charge composition experiment would study the range Z = 20 to Z =90.

Estimated Cost	$13M	Weight Volume	6000 lbs. 30 cu.ft.
Availability	CY 75		

3. Subsatellite Experiments - Two ionospheric plasma measurements would be carried as auxiliary experiments aboard a meteorology subsatellite operated from the manned station. Survey of the plasma properties surrounding the Space Station is accomplished using a group of electron and ion sensors located in the subsatellite. Measurement of the bulk properties of the ionospheric plasma is carried out by examination of the propagation characteristics of radio signals transmitted by the parent spacecraft and received by the subsatellite.

Estimated Cost (Instruments) (Subsatellite)	$1.0M 9.0M	Weight (Instruments) Volume (Instruments)	70 lbs. 1 cu.ft.
Availability	CY 74	Power Requirements	25 w

F. ENGINEERING/OPERATIONS

1. Man-machine Evaluations

Objectives: To determine the degree of degradation of human performance in space, to develop supporting facilities and procedures to overcome such degradation, and to acquire experience in man's performance of a wide variety of useful space operations, both IVA

and EVA, to enable early planning and design to optimize man's role in future space systems.

Background: The role which man should play in many areas of orbital experimentation may best be determined through careful examination of man's activity in support of similar activity on the ground; e.g. the role of man in a ground astronomical observatory. Based on this kind of data, a carefully planned set of operations is needed to test man's ability to use his mind, to make decisions, to carry them out with simple or complex manual tasks, to maneuver and pilot the spacecraft, to determine his position and orbit, to operate equipment and experiments, to make repairs and adjustments, to handle or filter data, to maneuver about inside or outside the spacecraft, to ensure mission reliability, to test emergency and safety procedures, etc. Supporting hardware such as maneuvering systems, handholds,zero gravity tools must be designed and tested. Complex science experiments requiring man as an operator, and complex spacecraft maneuvers requiring man as a pilot should be carried out and all results noted to provide future design data. Decisions must be made as to how much automation versus manned operations is desirable.

Experiment Description: Much of this program will be designed around the useful activities the astronauts should carry out with the spacecraft systems and the scientific experiments themselves. A limited set of test tools and hardware should be provided to support this program and suitable work area will have to be provided.

Operational equipment for maneuvering (both IVA and EVA) will also be required.

Further studies are required to provide a coherent and integrated plan of engineering and manned operations experiments in support of the orbital workshop program. Experiments in this category will include such activities as IVA, EVA, maintenance and repair, social and psychological interactions as well as the role of man as a sensing integrating, controlling and compressing data processor.

G. MATERIALS PROCESSING AND MANUFACTURING IN SPACE

Objective: To investigate the feasibility and explore the basic technology necessary for exploiting space as a medium for implementing manufacturing processes uniquely dependent on a zero gravity environment if and when transportation costs make such processes economically attractive.

Background: A number of manufacturing processes of interest to industrial concerns have been identified which offer promise because of the unique benefit afforded by a low or zero gravity environment. These include: 1) buoyance and thermal convection sensitive processes such as blending of variable density materials, casting of compacted and compound powders, and composite casting; 2) processes controlled by molecular forces such as cohesion and surface tension casting, layer casting, blow casting, and variable density casting; and 3) combined processes affected by both convection and surface tension.

Initially a program designed to investigate the basic feasibility of this concept and provide initial exploratory data required for its implementstion is necessary as a precursor step to its exploitation.

Experiment Description: To initiate this exploratory effort, two experiments will be developed to verify the concept and demonstrate this capability in two of the more promising areas: Cohesive casting of metallic spheres and variable density casting of metallic materials. Although the specific details for implementation of these experiments have not yet been fully identified, they should impose only modest requirement in terms of vehicle support and resources.

G. ADVANCED TECHNOLOGY

Objectives: To test advanced subsystems and materials in the space environment to provide design data for "next generation" spacecraft.

Background: Although this program is of significant importance, it is difficult to identify many technology experiments that cannot be done or simulated on the ground. Areas that may prove worthwhile are spacecraft fault location and repair, study of spacecraft environment, micrometeoroid puncture studies and "in-situ" composition analyses, space degradation of materials and surfaces, tests of complex

optical systems critically dependent upon zero gravity and deployment in space and use of large stm :tures such as antennas. Tests of subsystems elements where liquids, gases and solids interact and g-forces are normally important (as in fuel cells or elements of life support systems) may also be justified.

Experiment Description: In general no unique or special hardware is required for implementation of this program; rather most of the desired data can be obtained through systematic and controlled evaluation of new approaches and concepts utilizing ope ation spacecraft and experiment systems.

RELATIVE ORDERING OF EXPERIMENTS

It is important to recognize that regardless of how missions are ultimately structured, a strong experiments effort must constitute a major part of any successful earth orbital flight program. While the early workshop program emphasizes learning about man, man-machine interfaces, and operations in space, it has been repeatedly pointed out that man's capabilities and limitations in space will best be determined through evaluation of his performance in support of realistic scientific and operational activities.

Thus, in agreement with the goals and objectives expressed in preceding paragraphs, primary emphasis in the experiment program should be placed on those experiments which investigate, support and develop man's useful role in space and are ranked according to their contribution to this purpose. A relative ordering by discipline is as follows:

(1) Biomedicine and supporting Space Biology
(2) Biotechnology and Manned Operations
(3) Astronomy
(4) Earth Applications
(5) Advanced Technology (new space hardware and systems)
(6) Other Space Biology
(7) Space Physics

REFERENCES

1. "Guidelines for Planning Earth Orbital Space Station Payloads," Payloads Directorate, AMMP, OMSF, June 28, 1968

2. "Guidelines for Intermediate Space Station Payloads" - Case 710, Bellcomm/MTS, July 3, 1968

CONTENTS

SUMMARY

ASTRONOMY

OBJECTIVES

To operate large, high-performance, highly reliable telescopes and survey instruments above the atmosphere in order to study radiation from the sun, planets, and stars throughout the spectral regions from high energy gamma rays to long wavelength radio waves.

PROGRAM

The advantages of operating in space to avoid the spectral masking and geometric resolution limitations imposed by the atmosphere, together with the importance of astronomy to our understanding of the universe and to our future space program, make this field a high priority space effort. It appears at this time that manned systems can offer important assistance in providing large, high-reliability, long duration, versatile telescope systems in space. Hence, a well planned program in which one or more telescope systems is operated in conjunction with each manned space station seems warranted. The proper balance and sequencing between solar, stellar-planetary, gamma- and x-ray, radio and optical astronomy must still be worked out. A major question to be resolved is whether or not large telescopes of high resolution can be operated attached to manned stations, or must be flown as free, man-attached modules. Early data on ATM performance should help here. The program should progress through two or three stages of ATM's and perhaps and "ASTRA" to a very large

telescope facility (120") in the 1980's. A reasonable balance between the current automated OSO's, OAO's, SAS's and rocket flights, together with the manned program, is desirable.

The astronomy program which is summarized in this document has been developed with two primary ground rules in mind: to effectively gather meaningful scientific data as indicated by the scientific community; and to effectively develop a sound technology base as the program unfolds, which will provide the capability to confidently plan future missions.

The scientific program has been based principally on the output of the NASA PSG organization. Specifically, it was based on the manned portion of Astronomy Program Alternative number two of the PSG Astronomy Working Group with slight modification which will be explained later. The missions, which form the basic elements of the astronomy program, were defined in sufficient detail to allow both an indication of their scientific capabilities and to assess the general impact which they would have on manned orbital support facilities. Following is a list of the mission elements, or by our designation, Functional Program Element (FPE) contained in the astronomy program:

1. High Energy Module (FPE I)
2. ATM-B Solar Module (FPE II)
3. UV Stellar Module (FPE III)
4. UV Survey (FPE IV)
5. Hi Energy Stellar Survey A (FPE V)
6. Hi Energy Stellar Survey B (FPE VI)
7. Advanced UV Stellar (FPE VII)

8. Advanced Solar (FPE VIII)
9. Advanced High Energy (FPE IX)
10. Infrared and Sub-millimeter (FPE X)

Each of these Functional Program Elemtnts represent a different scientific capability, desired mission mode, technology level, and availability date. The Astronomy Program was generated by logically time-ordering each of these elements according to its scientific, technological and programmatic characteristics.

To provide an effective technology base, each of the more advanced missions were timed so that the definition phase of their development schedule overlapped with the development phase of an appropriate earlier mission and that the earlier mission was specifically designed to answer technological questions critical to the advanced missions. For example, the ATM-B Solar Module (Functional Program Element II) should be designed to answer question related to evaluating man's capability to conduct maintenance and repair operations; to operate both on-board the space station and in a remote detached mode to evaluate which of these modes offer the most promise for advanced missions. These two questions are currently felt to be very critical to the design of such future stellar missions as ASTRA (FUNCTIONAL ELEMENT VII).

In some cases it may be necessary to provide additional technology flights if serious gaps begin to develop in the technology base which can not be satisfied by scientific missions alone. Missions of this kind, although part of the overall astronomy program were not included in this document.

Upon reviewing the developme t program associated with each Functional Element, we felt that the order of the ATM missions occurring in the 1973-1975 as generated by the PSG Astronomy Working Group should be reversed. Based on the, the ATM-B Solar Module (Functional Element II) would fly late in 1974, and the High Energy Module (Functional Element I) would fly in late 1975. The final decision regarding flight sequencing of these missions will depend also on other factors such as scientific priority.

In this effort primary emphasis was placed on the 1970-1975 time period. The following paragraphs are devoted providing summary description of those Functional Program Elements which are expected to be implemented prior to 1975. More detailed element descriptions have beei prepared for all ten Functional Elements but are not included here.

1. FUNCTIONAL PROGRAM ELEMENT I

<u>High Energy Module</u>

This experiment package represents the first high-resolution X-ray study of celestial sources. It will provide both spatial and spectral resolution of point and extended galactic X-ray objects, as well as polarization studies, utilizing a grazing incidence imaging X-ray telescope.

In addition to providing valuable scientific data in the spectral range from about 2 to 200 Å, this payload would be designed to evaluate technological concepts toward development of larger and more sensitive X-ray instruments.

Specific experiments to be used in conjunction with the imaging X-ray telescope are:

a) High resolution grazing incidence X-ray telescope and field-imaging spectrometer

b) Curved crystal X-ray spectrometer

c) X-ray polarimeter

d) Maximum sensitivity X-ray detector

System requirements are simiiliar to those for ATM-A. Moreover, 360° roll pointing and 1 arc min roll stability is required. Instrument weights of about 1750 lbs. and power of about 1/4 to 1/2 kw will be required. Film return capability of about 250 lbs. per 56 days should also be provided. Orbital inclination and altitude are not critical.

Estimated cost (Instruments) $50M (ATM Carrier) 100M

Availability 1974

Availability and cost figures are based on the assumptions that possible polarimeter problems can be overcome (see FPE I).

2. FUNCTIONAL PROGRAM ELEMENT II

ATM-B Solar Module

This experiment package represents a logical extension in the field of solar astronomy from the ATM-A effort for continued observation of solar phenomena in the UV and X-ray range using instruments with minor refinements in spatial and spectral resolution and in pointing and scanning modes. The capability to provide high resolution motion pictures of the sun in white light, near UV and H also would be included.

In addition to providing advanced scientific data in solar astronomy, this payload should be designed to evaluate technological concepts leading toward development of more advanced astronomy observatories. Further it should provide a test bed for careful analysis of man's capability to operate and functionally support major experiment elements in earth orbit.

Specific experiment would include such instruments as:

1. UV spectroheliograph and spectrograph as initially proposed by NRL
2. UV spectroheliometer and UV spectrometer from Harvard Observatory.
3. Photoheliograph for high resolution motion pictures of sun in visible, UV, and H_{α} range.
4. X-ray telescope.

Pointing systems requirements are similar to those for ATM-A. However, systems design and packaging arrangements should be made more suitable for maintenance. Instrument weights of about 5500# and power of about 1/4 kw will be required. Film return capability of about 1000# quarter also should be provided. Orbital inclinations of 28° to 50° at attitudes from 200-300 N Mi will be satisfactory.

Estimated Cost (Instruments) $65 M (ATM Carrier) $100 M

Availability CY '74

3. FUNCTIONAL PROGRAM ELEMENT III

Large Aperture Non-Diffraction Limited UV Telescope

This particular telescope is a modification of the OAO Goddard Instrument Package. It is a 1 meter aperture system capable of conducting stellar observations of extended and point sources using spectrographic, photometric and [illegible] to the OAO instrument include designing designing critical subsystems for maintenance and servicing by the astronaut and adding the imagery and spectrographic capability

REVISION PENDING

taking advantage of man's presence for changing film. The telescope field of view is approximately 20 arc minutes and will require a 3-axis gimbal mount with a pointing accuracy of about $\pm$ 1 arc minute. It weighs about 2000-2500 pounds and requires less than 1/4 kw of electrical power. Orbital inclinations of 28°-50° at altitudes of 200-300 N miles are satisfactory.

Cost estimates (Instrument) \$25 M (ATM Carrier) \$125 M

Availability CY '74

EMR SURVEY GROUP

The EMR class of experiments involve a variety of high energy observations in the gamma-ray, x-ray, and UV regions of the spectrum. The general objective of these experiments is to provide broad range search capability to locate and observe high energy sources not accessible to earth bound astronomy. This initial group of high energy experiments would include three functional program elements, namely: Ultraviolet Astronomy, (FPE IV) High-Energy Astronomy A (FPE V) and High-Energy Astronomy B (FPE IV). The distinction between A and B are the required development times.

4. FUNCTIONAL PROGRAM ELEMENT IV

<u>Ultraviolet Astronomy-Survey</u>

The ultraviolet package would include two 6" UV cameras with selected filters, an all reflective UV spectrograph, and a Schmidt type image converter spectrometer all mounted on an independent stabilized platform with a TV link to the control panel. This program element will provide UV imagery of star fields and emission regions from 1800-3000 Å and spectral

photometric data in the 900 to 1800 Å regime.

This package (total weight under 600 lbs.) could be integrated into the OWS for launch with the platform (providing ± 30 arc sec stability for 15 min exposures) attached to a swing-out boom for operation. Power, (24 watts ave. 160 watts peak) telemetry (Housekeeping only) and a base stability of 10 arc min will be provided by the OWS. Film return capability of approximately 32 lbs. per 56 days will be required.

Estimate Cost: $4.805

Availability: Dec '71

5. FUNCTIONAL PROGRAM ELEMENT V

High Energy Stellar Astronomy A

This package consists of three experiments (1 X-ray and 2 γ-ray) that have undergone extensive definition for the past several years and consequently can be developed for flight without technological delays. The X-ray experiment is a large array of proportional counters for survey the entire celestial sphere, and would be operated in a scan mode. The γ -ray dectors, both scintillation counters, could be mounted on a common orientation system as they have similar desired targets and viewing times.

The base stability of 10 arc min of the OWS would be adequate for all of these experiments. The total weight, including all experiments and pointing mechanisms, would be 4,850 pounds, with a power demand of 248 watts on the OWS. The scientific data would add up to 1.7 k bits/sec. No film would be required.

Estimate cost $3.1 M

Availability June '72

6. FUNCTIONAL PROGRAM ELEMENT VI

High Energy Stellar Astronomy B

This program elements consists of four experiments, 3 gamma-ray and 1 x-ray. This group of experiments could be integrated into the OWS design, or if desired to better fit the total program, they could be packaged as a separate payload, launched later in the program, and then rendezvous and dock to the OWS for operation. Only the X-ray experiment requires finer stabilization than intended for the OWS, and this extra stability would be provided by the experiment. The gamma-ray experiments desire long viewing times (up to two weeks) on specific targets. They could use a common pointing mechanism, but it definetely should be independent of the OWS orientation. This pointing capability should extent over a minimum of one hemisphere.

This total would weigh approximately 8000 lbs. The power demands on the OWS would be 580 watts peak, 460 watts average. The desired data rate is 11.2 k bits/sec, but 7.2 k bits/sec. is acceptable. Film is not a firm requirement, but could be an added benefit if it fits within program limitations. A common item on this group of experiments is that they each represents a large step forward in technology. Consequently the development time is longer than for the High-Energy - B package. And the actual flight date could be slipped without harm to the science objectives of the experiments if the total astronomy program become too heavy for

budget limitations. But in this eventually it should be noted that these experiments will contribute very strongly to the technological growth of high-energy astronomy, and therefore should still receive immediate and continuing definition funding.

Estimated cost	$17.5 M
Availability	June '74

FUNCTIONAL PROGRAM ELEMENT I

HIGH ENERGY MODULE

1. DISCIPLINE - Astronomy

2. PROGRAM ELEMENT - High Energy Module - Grazing Incidence X-ray Telescope

3. REQUIREMENT

   a. Provide high-resolution imaging and spectroscopy of x-ray sources.

   b. Provide the technology base for larger grazing incidence x-ray telescope.

4. JUSTIFICATION

   a. Focusing x-ray telescope necessary to provide spatial resolution to study point sources, structure, intensity, and to provide high spectral resolution.

   b. Technology development necessary to provide for very large x-ray telescopes to provide high sensitivity.

5. COMPONENT EXPERIMENTS

   a. X-ray Polarimetry

   b. Curved Crystal X-ray Spectrometer

   c. High-Resolution Studies of X-ray Sources

   d. Maximum sensitivity x-ray detector

6. DESCRIPTION

The x-ray polarization, sensitivity, spectroscopy, and image experiment require an x-ray imaging system of good resolution and significant collecting area. In the suggested system x-rays are incident on a paraboloid mirror surface, from which they are reflected to a hyperboloid,

and then to the focus. The mirrors are practically in the form of cylinders, and several (up to five) two-mirror systems are used, each inside the larger ones, to provide a large total collecting area. Each two-mirror system is therefore a unique form of Cessegrainian. The outer mirror system has a diameter of approximately 30 to 36 inches, and the focal length of the system, which is the distance from the plane of intersection of the two mirrors to the focus, is 20 feet
The apparatus of each experimenter is placed at the focus of this morror system. The experiments are arranged near the focus on a suitable structure, so that each one may be moved into place as required.

7. SPECIAL CONSIDERATIONS

a. The polarimeter and sensitivity experiment may use solid or liquid hydrogen and would thus requires cyrogenic equipment. There is some question regarding the technological feasibility of this experiment, especially concerning the use of solid or liquid H_2.

b. Total weight about 1500 lbs. plus 250 lbs. of cyrogenics.

c. Size: Telescope, about 3 x 20 feet. Instrument package, about 35 cubic feet (maximum length 40 inches).

d. Power requirement about 250 w average 360 w peak, excluding cyrogenics.

e. Orbit: 28^{o}-50^{o}, 200-250 mm.

f. Pointing stability required: 2 arc sec. for 1/2 hour, 15 arc

sec. for 3 hours.

g. Telescope must have roll stability of about 1 arc min.

8. <u>COST</u>

(Instrument) \$50M (Module) \$100M

EXPERIMENT DATA SHEET

X-RAY POLARIMETER

1. SCIENTIFIC OBJECTIVE

The objectives of the polarimeter are to provide precise measurements of the polarization of X-radiation from a large number of X-ray sources in the energy region between roughly 1 and 4 KeV. This polarimeter could be used to map the polarization within the disc of such interesting objects as the Crab Nebula and the M87 radio galaxy.

By measurement of the polarization of astronomical X-ray sources, knowledge can be gained about the originating mechanisms of such radiation. Detection of non-zero polarization would be convincing evidence that at least part of the radiation is of the synchrotron type emitted when electrons are accelerated by a magnetic field. Polarization measurements on X-ray sources such as the Crab Nebula and Sco XR-1 are needed to determine if the X radiation of these objects is of the synchrotron type.

2. GENERAL DESCRIPTION

a. Equipment

The polarimeter is placed at the focus of telescope. The basic part of the polarimeter is the scatterer contained in a tube, 1 inch diameter and 13 inches long. This tube will probably be filled with solid H_2, although liquid hydrogen still may be considered. The tube is a 90-percent transparent

perforated silver tube sealed with aluminized mylar. Eight Geiger counter-type detectors surround the scatterer. These detectors are about 1.25 by 2.125 by 13 inches long and have metallic (aluminum) housings with aluminized mylar windows. It is proposed that the detectors be at liquid nitrogen temperature (77° K). It is likely that neon will be the fill gas for the detectors since neon has a boiling point below 77° K and has a high X-ray absorption coefficient in the 1 to 4 keV range. It will be contained in a complex assembly necessary for the preservation of the H_2 in a solid (or liquid) state. The scatterer and surrounding detectors will be positioned in the telescope with one end of the scattering tube at the focus and aligned along the optical axis. In order to eliminate instrument assymmetries, it will be necessary to rotate the polarimeter about the line of sight. Provisions must be made for rotating the telescope and polarimeter in a suitable set of gimbals, probably internal to the ATM structure itself. There will also be an electronics package for the recording of pulses from the detectors.

b. Operation

X-rays from the nested mirror concentrator are brought to a focus at the end of the scattering tube. A diaphragm is used to isolate the region of the image to be studied. X-rays are scattered in the solid (or liquid) hydrogen by Thompson scattering at right angles to the direction of the electric vector of

the incident X-ray. The eight detectors measure the distribution of the scattered photons, and the orientation of the plane and degree of polarization of the X-ray flux from discrete sources in space is thereby determined.

3. OPERATIONAL CONSTRAINTS - See Item #7, FPE.

4. MODE OF OPERATION

Automated, continuous operation. Man tended for maintenance as required.

5. CREW SUPPORT

Familiarity with equipment and cryogenic system necessary for maintenance as required.

6. SPACECRAFT SUPPORT

See Item #7, FPE.I Instrument dimensions 40 inches long X 26 inch diameter.

7. DEVELOPMENT SCHEDULE

At least five years from definition to flight. The use of solid or liquid H_2 may pose a serious developmental problem.

EXPERIMENT DATA SHEET

CURVED CRYSTAL X-RAY SPECTROMETER

1. SCIENTIFIC OBJECTIVES

Two objectives are considered for this experiment; they are as follows:

a. It is proposed to examine detailed features of the line and continum emission spectra and absorption spectra of 10 to 15 of the now known X-ray sources in the 1.5 to 25 angstrom region. The spectrometer would have superior resolution to the objective grating.

b. It is also proposed to make a random sky in search of additional not now known cosmic X-ray sources and to measure the intensity, energy spectrum and isotropy of the cosmic X-ray background within the capabilities of the instrumentation. This new data should determine the types of emission mechanisms and sources that are present.

2. GENERAL DESCRIPTION

a. Equipment

The X-ray spectrometer consists of an image detector, a curved-crystal dispersive element and an X-ray spectral line detector. The image detector is placed at the focus of the X-ray image forming telescope. The image detector is composed of a hexagonal honeycomb of individual Geiger tubes with 0.19 mg/cm^2 mica windows. These tubes are sensitive in the range from

8 to 20 angstroms and are surrounded by an anticoincidence shield of CsI viewed by a single photomultiplier. The image detector has a small hole in the center for the passage of X-rays. The spectrometer is a Cauchois focusing instrument with the image detector, curved crystal and line detector all located on the Rowland circle of the crystal. The X-ray line detector also consists of a honeycomb of Geiger tubes surrounded by a CsI anticoincidence shield and two photomultiplier tubes. The associated electronics is also considered a part of the spectrometer system.

In addition, there will also be a console for handling displays, housekeeping information, controls for the detection system, an in-flight computer for automatic programming of the experiment procedure, and telemetry interface.

b. Operation

X-rays focused by the objective-mirror system are brought to a focus at the image detector. This will detect the position of an X-ray image anywhere in a 2-degree field of view. The image is centered, and the X-rays makings up the image dispersed and focused on the detector. The spectrum is scanning by moving the spectral line detector along the Rowland circle while simultaneously rotating the curved crystal.

3. <u>OPERATIONAL CONSTRAINTS</u> - See Item #7, FPE #I.

4. MODE OF OPERATION

Automated, continuous operation. Man tended for maintenance as required.

5. CREW SUPPORT

Familiarity with equipment necessary for maintenance as required.

6. SPACECRAFT SUPPORT

See Item #7, FPE # I. Instrument dimensions 16 X 16 X 10 inches plus 24 X 24 X 18 inches electronics package and console. Data rate 250 bps.

7. DEVELOPMENT SCHEDULE

Five years from definition to flight.

EXPERIMENT DATA SHEET

HIGH-RESOLUTION STUDIES OF X-RAY SOURCES

1. SCIENTIFIC OBJECTIVES

The X-ray region to be investigated is the range 0.2 keV to 4keV. Four types of observation are anticipated.

They are:

a. Moderate resolution spectrograms ($\lambda / \Delta\lambda = 40$ at $\lambda = 10 Å$ of point or highly structured X-ray sources of intensity greater than 10^{-2} of Sco X-1 by use of a dispersive grating.

b. Broadband (filter) spectroscopy of diffuse and point X-ray sources of intensity greater than 10^{-4} of Sco X-1

c. Detection of X-ray sources of intensity greater than 10^{-5} of Sco X-1. Precision of location down to the faintest sources will be the order of 1 arc second.

d. Determination of angular size and structure of diffuse sources of intensity greater than aoubt 10^{-5} of Sco X-1, depending on the actual angular size.

The proposed instrument has a sufficient sensitivity for the discovery of a significant number of X-ray sources. The instrument will be used in the above modes for the following studies:

a. Investigation and Study of Sources

(1) Observation of isolated X-ray sources in nearby galaxies. It should be possible to study many sources similar

to the Crab Nebula in nearby galaxies, such as M31.

(2) Observation of the ordinary coronal X-ray emission of nearby stars. This should be possible for stars at less than 5 parsecs distance in the range from 200 eV to 1 keV.

(3) Observation of M87-type X-ray sources.

b. Effects of interstellar absorption. This program affords the opportunity of measuring the column density out to large distances in the galactic disc.

c. Spectral measurements.

d. Observation of spectral line absorption edges.

e. Solar related experiments

(1) Measurement of density and scale height in the chromosphere.

(2) Observation of gravitational light bending.

2. GENERAL DESCRIPTION

a. Experiment

The instrument consisting of a filter wheel, X-ray imaging device and camera or low-light vidicon is placed at the focus of the X-ray image forming telescope. An X-ray diffraction grating with approximately 10^4 rulings per centimeter is placed either in front of or behind the mirror system of the X-ray telescope.

If photographic film is used as the primary means of data storage, the bulk of the electronics will be digital. If

video readouts are required, the electronics is probably still within the state-of-the-art. The only unique circuit element is a jitter removal system.

b. Operation

The convergent X-ray beam from the X-ray telescope first passes through the filter wheel. The beam is focused on the face of an X-ray imaging device, which is made up of many glass tubelets similar to a fiber optic assembly. X-rays entering the releases electrons by surface photoelectric effect. These electrons cascade along the tubes and result in pulses of 10^4 to 10^5 electrons, which are focused onto a visible light phosphor. The image is then photographed or viewed with a low-light level vidicon. Objective grating spectra may be obtained by use of a grating either in front of or behind the objective mirror system.

3. OPERATIONAL CONSTRAINTS - See Item #7, FPE # I.

4. MODE OF OPERATION

Automated, continuous operation. Man tended for maintenance as required.

5. CREW SUPPORT

Familiarity with equipment necessary for maintenance as required.

6. SPACECRAFT SUPPORT

See Item #7, FPE # I. Instrument dimensions 22 inches long X 16 inches diameter, plus 4.5 cu. ft. of electronics and at least 5 film packages of 3/4 cu. ft. each per 56 day interval.

7. DEVELOPMENT SCHEDULE

Five years from definition to flight.

EXPERIMENT DATA SHEET

MAXIMUM SENSITIVITY X-RAY DETECTOR

1. SCIENTIFIC OBJECTIVE

The reflective properties of the telescope optics impose a short wavelength cutoff of about 3 A for experiments at the focus. There is also an effective low energy cutoff imposed by interstellar absorption, so that observed spectra are expected to peak at $\lesssim$ 10 Å. A detector with efficiency close to 100% in the range ~3 - 20 Å is, therefore, highly tuned to detect stellar X-ray sources.

2. GENERAL DESCRIPTION

The detector proposed will use cooled Si(Li). Recent experience has been obtained with cooled crystal detection systems of this type, and all of the detector characteristics which are described are presently available. The rate of progress in the development of these devices is presently quite rapid, so that one may reasonably expect to have even better crystals available in the near future.

The detector consists of three separate crystal elements mounted on a single coaxial cold finger cooled to liquid nitrogen temperature or less. The dotted faces of the crystals presently have dead-layer windows of less than 0.5 microns (~500 eV photon attenuation length), while the solid faces are ~50 microns. The V-shaped grooves on the crystals are used to separate field domains; outputs may be taken separately, in fact, from the internal (A) and external (B) portions

of the central crystal. The primary mode of operation of the device is $\overline{ABCD}$, where B, C and D offer virtually complete anti-coincidence and anti-Compton shielding of the A detector.

The best presently available resolution with such devices at liquid nitrogen temperature is $\approx$250 eV FWHM in this energy range. This resolution worsens with detector capacitance (as the area increases), but the most serious limitations at present are state-of-the-art low-noise preamplification techniques and crystal leakage currents. One could expect, however, within the framework of the present technology, to achieve $\lesssim$ 500 eV FWHM with the proposed detector.

THE MODULATION COLLIMATOR

A modulation collimator composed of thin wires is to be placed in the focal plane, in front of the detector. In principle, the limiting angular resolution of this device is:

$$\frac{\text{wire diameter}}{\text{focal length}} = \frac{\text{n mils}}{\text{20 feet}} \approx \text{n arc second.}$$

At present, uncertainty exists as to how thin the wires can be made for reliable performance. It is known that 5 mil wires may be used reliably, but doubt exists as to wires as low as 1 mil; 3 mil is probably a fair estimate. The thin wires of the modulation collimator are to be mounted on a disk that rotates at a constant angular speed (w).

The modulated temporal response of the detector should be directed to:

(a) a strong point source image at P

(b) a weak point source image at P

(c) a strong extended source image at P

assuming no internal detector background. The periods T_1 and T_2 are defined by the rotational frequency of the collimator only, so that these provide a powerful framework for the data reduction (i.e. the data for the entire source exposure, or any fraction of it, may be frequency-analyzed). The local value of T_1 or T_2 will be known independently, since it is planned to use a geared-down drive for the collimator rotation, so that a monitor of the motor rpm will predetermine T for any time interval.

The image point P is located on the focal plane by the coordinates ρ and θ. It can be seen that the "bunching" time τ for the observed counts measures the coordinate P and that the phase ϕ measures the angle θ. T and ϕ are determined by a frequency analysis of the data and correlation with the rpm monitor of the disk motor drive by superposing epochs in the exposure. As shown below, the accuracy to which T may be obtained (hence P) is a more sensitive function of how well T is known than of the statistical uncertainty of the data.

Since both the precision with which T is known and the percentage variation in T both become better with increased motor speed, it is advantageous to have as large a gearing ratio as practical. The geared-down angular velocity of the collimator itself should be determined by

the telescope jitter. If the assumed jitter is ~1 arc second per temporal second, one would select a value of on the basis of the strongest source to be located, so that the telescope jitter would not be larger than the uncertainty with which the collimator can locate the source. For a strong source, one would want $T_1 \approx 0.1$ second, which would correspond to one complete revolution of the collimator in ≈ 20 seconds, or ≈ 3 rpm.

3. OPERATIONAL CONSTRAINTS - See Item #7, FPE.

4. MODE OF OPERATION

   Automated, continuous operation. Man tended for maintenance as required.

5. CREW SUPPORT

   Familiarity with equipment and cryogenic system necessary for maintenance as required.

6. SPACECRAFT SUPPORT

   See Item #7, FPE I Instrument dimensions 40 inches long X 26 inch diameter.

7. DEVELOPMENT SCHEDULE

   At least five years from definition to flight. The use of solid or liquid H_2 may pose a serious developmental problem.

FUNCTIONAL PROGRAM ELEMENT II

ATM-B - SOLAR

1. DISCIPLINE - Astronomy

2. PROGRAM ELEMENT - ATM-B - Solar

3. REQUIREMENT

   a. Extend our knowledge of solar phenomenon through the use of high resolution visible U.V., and X-ray imagery techniques; XUV and X-ray spectrographic techniques.

   b. Improve the optical technology base which is required for the design and development of more advanced space solar observatories.

   c. Develop design criteria and operational techniques for effective utilization of man in space to provide assistance in data taking, routine servicing and to provide an improved mission success probability through maintenance and repair capability.

4. JUSTIFICATION

   a. The need to more thoroughly understand Solar phenomena is based on two requirements; first, the sun, through its emission of particulate and electromagnetic energy, has a direct effect on the earth's atmosphere, surface and magnetic field. Second, through study of the sun, the nature and evolution of stars and source and evolution of stella-energy can be better understood.

   b. To eventually conduct studies of detailed features of the

sun's granular structure, large 1-2 meter aperture solar telescopes will be required. Also, high spectral and spatial resolution studies in the XUV and X-ray will require the development of new reflective coatings and mirror fabrication technique. The experiments proposed for this flight form a technological stepping stone toward these more advanced missions.

c. The more advanced astronomy missions which are envisioned for the late 1970's and early 1980's will involve the use of multipurpose, large, long life time telescopes. For these missions to be successfully carried out it is essential that they be designed so that man can service, update and maintain them. In order to do this we must obtain from earlier missions, adequate design criteria and operational techniques so that man's proper role is determined and his effectiveness improved to the point where he can be relied upon with confidence.

With these factors in mind, the design of this experiment module should include provisions for evaluating man's capability in the following areas:

1) Maintenance and repair
2) Instrument checkout, calibration, adjustment and updating.
3) Data handling
4) Selection of targets

5. COMPONENT EXPERIMENTS

   a. Ultraviolet Spectroheliometer and Spectrometer and H- Telescope Camera (S055 A and B).

   b. Photoheliograph by C.I.T.

   c. X-ray Spectroheliograph.

6. DESCRIPTION

The three experiments contained in this module will be bore sighted on one mount so that they all look at a common target. Those experiments which are designed to look at the particular portions of the sun will be either capable of scanning the sun independently through internal optical arrangements, or they will be time shared and the entire mount moved on a priority base as is now done on ATM-A.

In the design of this module, particular attention will be paid to designing the telescope and module subsystems for repair and maintenance by the astronaut. This will involve the possibility, because of the potentially dramatic increase in astronaut capability, of designing the module so that the telescope and critical module systems can be serviced in a shirtsleeve environment without the necessity for EVA. The module and its scientific payload will be analyzed to determine which subsystems are likely candidates for in-flight maintenance, the degree of fault isolation which is desirable, proper location of subsystems for adequate accessability, spare parts requirements, and tools.

The module will make use of ATM-A technology and hardware to the maximum practical extent. Also, the module will be designed so that it can be launched on a separate vehicle, rendezvoused and docked to the space station for operation.

7. SPECIAL CONSIDERATIONS

Orbital Inclination	28° to 50°	
Altitude	200-300 N. Miles	
Space Station Stabilization	10 Arc Min.	
Mission Mode	Attached to Space Station	
Total Module Weight	20-25,000#	
Digital Data Rate	S055 A&B	3.3 K bits/sec
	Photoheliograph	101.0 K bits/sec
	X-ray Spectrohiograph	2.2 K bits/sec
	Total	106.5 K bits/sec

The photoheliograph experiment, because of its relatively high data rate requirements, may present a telemetry problem which can not be satisfied in the time frame envisioned. If this is so, the experiment has an alternate design utilizing film.

Power required	Approximately 3.0 KW average
Film return	Approximately 600 lbs every 60 days with an average volume of ft^3

8. COST

Experiment cost -	S055	22 M
	Photoheliograph	14 M
	X-ray Spectro-heliograph	14 M
	Subtotal	65 M
	Module Cost	100 M
Total cost of module and experiments		150 M

EXPERIMENT DATA SHEET

ULTRAVIOLET SPECTROHELIOMETER AND SPECTROMETER AND H-α TELESCOPE CAMERA

1. SPECIFIC OBJECTIVES:

A. Ultraviolet Spectroheliometer (S055A)

The purpose of the experiment is to obtain high-resolution spectroheliograms of local features on the solar disc in eight wavelengths between 300 and 1400 angstroms. The quiet sun data will provide temperature and density gradients near the limb and across supergranulation boundaries in the photosphere. Any flares of class I or greater will provide spatially resolved and spectrally resolved data not otherwise available.

B. Ultraviolet Spectrometer (S055B)

The ultraviolet spectrometer makes high-resolution spectrograms of very localised areas of the sun, primarily near and at the limb. The solar spectrum in the wavelength region 1400 to 2250 Å consists predominantly of a continuum with overlying absorption lines. Observations of the continuum and spectral lines in this region made with high spatial (1.5 arc seconds) and spectral (0.08 Å) resolution will yield valuable information about the physical conditions in the transition region between the photosphere and chromosphere.

C. Hydrogen-alpha Telescope (Camera)

The Hα telescope will provide reference data for the other ATM

experiments and specifically pointing for S055. Returned photographs in H_α (6563 Å) can be compared with solar patrol photographs from ground observations to identify exactly when data was taken in the unlikely event that other reference data slips in time or is lost.

2. GENERAL DESCRIPTION:

A. S055A

A large telescope mirror focuses the sun image on the entrance slit of a grating spectrometer. The mirror is driven in two axes to raster scan a square of 5 by 5 arc minutes. Eight channeltron photomultipliers are located at the focal surface of the spectrometer to pick up image signals at the eight selected wavelengths. The data is taped and dumped to ground stations.

B. S055B

The instrument consists of a fixed-position, primary telescope mirror, adjustable (in pitch and yaw) secondary mirror, and plane-grating spectrometer with two UV detectors and data channels, and a white-light zero-order analog channel. The grating is motor driven in one axis to perform wavelength scans from 1400 to 2250 Å in about 12 minutes/scan. Fine pointing is accomplished by a 5-arc-minute field of view H_α telescope/TV camera system which views the entrance slit of the spectrometer through an H_α filter. The slit jaws are polished to mirror smoothness and reflect to the telescope that portion of the sun being viewed by the spectrometer.

C. H_α Camera

The instrument consists of a telescope, H_α filter of 0.9 angstrom bandwidth and a beam splitter. One part of the beam will be imaged on 35mm film. The other part will be displayed on the astronaut's console through a vidicon system. The H_α filter will be thermally tuned.

3. OPERATIONAL CONSTRAINTS:

See Functional Program Element - II

4. MODE OF OPERATION:

A. S055A

Targets of interest aside from quiet Sun patrol are flares, faculae, the limb, and the boundaries of supergranulation. Flares are monitored by line scanning without raster so that spatial and extremely fine time resolution of flare history is acquired. Pointing is aided by the TV display of the H_α slit camera image of the S055B pointing-reference system. About a half arc minute is the pointing accuracy required.

In patrol mode the instrument points to a selected region of the Sun, and the raster scan, which takes five minutes, runs continuously while in view of the Sun. In flare mode the pointing and orientation are controlled by S055B (the UV spectrometer). For other features the astronaut points to coordinates specified by ground communication.

B. S055B

The astronaut will point to several different points along a common radius and also at the limb, executing a wavelength scan at each point. The spectrometer slit will be perpendicular to the radius of each point, and thus tangent to the limb. The wavelength scan time of 12.5 minutes will allow a maximum of nearly 4 scans per orbit. It will, therefore, be desirable to reposition the instrument along the same radius for two successive orbits with roll controlled to within ±1°. This will permit building up a number of intensity profiles for the continuum, absorption lines, and emission lines such as Si I, Si II, and C IV. The spatial scans of the quiet Sun to be obtained with the spectroheliometer will be made when the spectrometer is performing center to limb scans.

Other Operation Mode considerations can be found in Functional Program Element - II.

5. CREW SUPPORT:

See Functional Program Element - II.

6. SPACECRAFT SUPPORT:

	A	B	Camera
Weight (lb)	325	478	220
Power (watts) Average/Max	20/20	18/36	20/30
Volume (ft^3)	12.8	20	10
Telemetry (bits/sec digital)	2525	800	voice
Pointing	Pitch & Yaw	±2.5 sec, Roll	1.0 min.

EVA and/or a capability for providing a shirtsleeve environment shall be available for servicing operations.

7. DEVELOPMENT SCHEDULE:

Currently being developed for ATM-A program. Should be available by 1972-73.

8. COST: $21.5 million total cost.

EXPERIMENT DATA SHEET

PHOTOHELIOGRAPH

1. **SPECIAL OBJECTIVE:**

High-resolution motion pictures will be taken of the Sun in white light (4000 to 6000 Å), near ultraviolet (2000 to 3000 Å), and at H_α (6563 Å). These pictures will be used to study solar granulation, sunspot structure, and the solar chromosphere.

2. **GENERAL DESCRIPTION:**

The instrument consists of a 65-cm aperture, folded, Gregorian system which will nominally resolve about 0.2 arc second. The solar images will be recorded on film which will be replaced and retrieved by the astronaut through EVA. (The principal investigators have suggested that there exist substantial advantages in using image-tube electronic detection methods instead of film)

Solar images will be available to the astronaut by means of a television link to facilitate focusing, alignment, and pointing of the instrument. A low-rate data channel will be required to telemeter a solar television image to the ground for evaluation of instrument performance by the investigators. A voice link between the astronaut and investigators will also be required.

3. **OPERATIONAL CONSTRAINTS:**

See Functional Program Element - II

4. MODE OF OPERATION:

The astronaut will be required to point the instrument at a selected region of the Sun and to focus and align the telescope by operating the drive mechanisms from the LM ascent stage cockpit. By observing the signal characteristics on the television screen, he will be able to position the mirrors and cameras for optimum focus. Manual adjustments will be provided which could be used during EVA. He will then turn the film cameras on and place the television in a standby mode. Periodically, the television image will be telemetered to Earth by switching the system to the slow-scan mode. The majority of the time, the television system will be in the normal mode with the astronaut observing optical quality and making the necessary adjustments.

Also see Functional Program Element - II.

5. CREW SUPPORT:

See Functional Program Element - II.

6. SPACECRAFT SUPPORT:

Weight (lbs)	700
Power watts Average/Max	130/280
Volume (ft^3)	44.4
Telemetry	101 K bits/sec
Pointing	See Functional Program Element - II

7. DEVELOPMENT SCHEDULE:

Approximately 5 years from design initiation to launch.

8. COST:

69	70	71	72	73	74
125K	450K	5.5M	5.8M	2.4M	400K

NOTE: These costs are based on an initial program schedule which called for a completion data on year earlier than is shown. The additional cost incurred by slipping the program for one year is not factored into these figures.

EXPERIMENT DATA SHEET

X-RAY SPECTROHELIOGRAPH

1. SPECIFIC OBJECTIVE:

The proposed experiment is designed to measure simultaneously the solar X-ray spectrum (approximately 1 to 25Å) with a spectral resolution approaching the crystal diffraction limit, a spatial resolution of a few seconds of arc, and a temporal resolution of 1 second.

2. GENERAL DESCRIPTION:

The proposed instrument actually consists of three bore sighted telescope operating simultaneously.

A. A graying incidence X-ray telescope for recording high resolution images.

B. A collimated plan crystal spectrometer.

C. A grazing incidence X-ray telescope with a Johann mount crystal spectrometer.

The overall size is approximately 110 inches long, 34 inches wide and 40 inches high.

3. OPERATIONAL CONSTRAINTS:

See Functional Program Element - II.

4. MODE OF OPERATION:

See Functional Program Element - II.

5. CREW SUPPORT:

See Functional Program Element - II.

6. SPACECRAFT SUPPORT:

Weight (lbs)	640
Power (watts) Average/Max	250/350
Volume (ft^3)	40 ft^3
Telemetry	See Functional Program Element - II
Pointing	See Functional Program Element - II

Also see Functional Program Element --II.

7. DEVELOPMENT SCHEDULE:

From initiation of experiment design to delivery will require 3-1/2 years. At least an additional 1 year should be added for integration and launch operations.

8. COST:

Total estimated experiment cost is $14 million.

FUNCTIONAL PROGRAM ELEMENT III

ATM UV STELLAR

1. DISCIPLINE - Astronomy

2. PROGRAM ELEMENT - ATM UV Stellar

3. REQUIREMENT

   a. Provide astronomical capability beyond OAO and sounding-rocket investigations. Observations in the few ultraviolet astronomical sources will provide unique and hitherto unobtainable records of images and spectra of star clusters, nebulae, and galaxies.

   REVISION PENDING

   b. Provide a necessary step toward the development of a national space astronomy facility.

   c. Determine the usefulness of man in the operation and maintenance of larger astronomical space telescopes by providing actual experience with a versatile telescope system requiring only moderate technological advancement.

   d. Provide a means to test techniques useful to the development of more advanced optical telescope systems and detectors systems for space astronomy.

4. JUSTIFICATION

   a. Optical astronomy is the only means of providing comprehensive information concerning the morphology of galactic and

extragalactic astronomical objects. A telescope of this type can provide ultraviolet images and spectra of these objects, thus extending our knowledge of their chemical and dynamical structure beyond that observable from the ground or by existing space techniques.

b. Although existing technology is believed adequate to provide pointing accuracies of the order necessary for this system, verification of new design approaches and system operations are essential for design and development of follow-on stellar observatories. Satisfaction of these technological objectives is equally important to the satisfaction of scientific objectives. Investigation of various operating modes such attached or detached, for a large stellar observatory is urgently required. Opportunity is presented here for a realistic comparison of observational techniques, and the impetus to develop and evaluate useful detector systems makes an extremely important contribution to all areas of optical astronomy.

c. Man's capability to operate and functionally support a major stellar observatory is only established through evaluation of his performance in early systems, thereby providing basic design and performance data for development of future systems. Design of this initial observatory should accommodate provisions for evaluating man's capability in the following areas:

1) Maintenance and repair

2) Set-up, check-out, calibration, adjustment and refurbishment

of detectors and instrument systems.

3) Data handling and analysis

4) Target acquisition

5. COMPONENT EXPERIMENTS

1-Meter aperture Ritchey-Chretien telescope with UV image and spectrum detectors.

6. DESCRIPTION

The all reflecting UV Stellar Telescope of approximately 1 meter aperture is of the Cassegrainian design and requires 3-axis gimbal mounting and active internal optics to provide the necessary pointint accuracy. The telescope will have a field of view of about 20 minutes and will provide both spectrographic and high resolution photographic analysis of point source and extended objects in the ultraviolet between 900Å and 4000 Å. It will include an array of suitable ultraviolet detectors and spectral analyzers, and the means to choose the mode of detection. The spectral range between 1050 Å and 4000 Å will employ ultraviolet image convertors to increase the sensitivity and spectral selectivity of the system. Schumann type photographic emulsion will be used below 1050 Å. Filter and gratings will be used for spectral analysis of the ultraviolet radiation. Ultraviolet images of extended objects over a field of view of 20 arc minutes will be recorded with a resolution of 1 arc second or better. Both photographic films and television detectors will be used forimage read-out.

Man will be able to test his capabilities in assisting in the operation and maintenance of the telescope, initiating the pointing and monitoring the target acquisition; selection of the instrumentation mode, adjusting control such as focus, exposure times, detector function; and monitoring the system performance. He will assist in the handling of the film and replacement of detectors, and evaluate the data results in order to improve and update the observing program and techniques. This comprehensive involvement of man will provide the necessary experience products required in the design of future more demanding optical astronomy telescope systems such as ASTRA and the NASO, for which such design parameters are completely lacking at present. Automatic modes of operations will be included to insure the mission's scientific objectives in the event of unknown limits on man's capabilities. By specific intent,, this telescope has been designed to provide an abundance of useful new scientific data by means of currently familiar technology. Nevertheless, it provides an ideal system by which technology can be significantly advanced, without impairing the success of the mission if such improved performance is not realized. Areas where advances in technological development can be evaluated include:

1. Telescope suspension, pointing and stabilization systems, attached or detached modes of operation.
2. Internal optical or electronic image motion compensation systems.

3. Imaging detector systems, including ultraviolet image convertors and digital high resolution, high sensitivity and low noise television detectors.
4. Photographic detector systems, including improved ultraviolet films, radiation resistant materials or techniques, in-flight film development techniques.
5. High performance large optics. Materials and fabrication methods suitable for production of near diffraction-limited optics. Mechanical suspension and thermal environment control techniques. In-flight evaluation of the telescope's optical performance would be possible, to the diffraction limit for brighter stars, even though the system need not meet such stringent performance requirements to perfectly carry out the scientific objectives.

The telescope including light baffle requires a cylindrical volume of about 80 inches in diameter and 200 inches long, will weigh about 2000 pounds, consume about 300 watts peak power. Gimbal weight, size, and power would add to these requirements. The useful scientific lifetime of this instrument is unlimited, but a design life of at least 2 years would be reasonable from an overall mission standpoint. Film and detector resupply would require no more than a few hundred pounds logistic weight per quarter. Telemetered data will require about 107 bits per

orbit, and an average of 5 pictures/orbit.

The telescope could be used in either attached or detached mode, the actual choice depending on mission configuration possiblities. The attached mode would permit direct optical viewing of the telescope field b the observer, which is deemed a desirable feature. Target acquisition and coarse stabilization would be provided in by a 180° gimbal mount, and by the daughter spacecraft if detached. Fine stabilization is provided by offset star trackers which drive an optical element of the telescope system, on the electronic image of the image converters.

Manned attendance of this system will require about 100 man-hours per quarter.

7. SPECIAL CONSIDERATIONS

Low Orbital inclination and low altitude (below about 300 N. mi) are preferred to reduce radiation exposure. Support systems must provide coarse stabilization to within 1 arc minute for the telescope. The telescope may be either attached or detached from space station, but will not require EVA for normal operation or resupply. The system should be designed for independent launch and automatic renezvous and docking. With the light baffle, the telescope will be able to make observations on the daylight side of the orbit as well as the night side.

8. <u>COST</u>

(Instrument) $25 M (ATM Carrier) $125 M

EXPERIMENT DATA SHEET

1-Meter UV Ritchey-Chretien Telescope

1. SPECIFIC OBJECTIVE - The experiment is completely incorporated in the functional program element for the 1-meter U.V. Ritchey-Chretien Astronomical Telescope.
2. GENERAL DESCRIPTION - See functional program element, III item 6.
3. OPERATIONAL CONSTRAINTS - See functional program element, III item 7.
4. MODE OF OPERATION - See functional program element, III item 7.
5. CREW SUPPORT - See functional program element, III item 7, for duties. The telescope should be manned by an astronomer on the space station. Man assisted observations will require 12 hours per day maximum.
6. SPACECRAFT SUPPORT - See functional program element, item 6.
7. DEVELOPMENT SCHEDULE -

   Phase A - completed

   Phase B - in progress, completion date, June 1969.

   Phase C - completion date, Jan. 1971.

   Phase D - completion date, June 1973

   Flight Ready - June 1973.
8. COST -

FY 1969	.25 M
1970	2.0
1971	4.0
1972	8.0

FY 1973	8.0 M
1974	1.5
1975	1.25
TOTAL	25.0 M

FUNCTIONAL PROGRAM ELEMENT IV

UV SKY SURVEY

1. DISCIPLINE - Astronomy

2. PROGRAM ELEMENT - UV Survey - Imagery & Spectrometry

3. REQUIREMENT

   a. Conduct an ultraviolet photographic survey of the sky

   b. Obtain spectra in the UV region from selected stron UV sources, and the entire celestial sphere.

   c. Provide survey data of selected areas for detail investigation by larger instruments to follow.

   d. Develop a UV technology base and determine man's potential in support space astronomy.

4. JUSTIFICATION

Since earth-based telescopes are limited in spectral range due to the atmospheric cut-off in the UV, the celestial sphere has been surveyed in this region. Only information obtained from short duration sounding rockets is now available on very limited areas of the sky. The entire sky needs mapped in the UV, with special emphasis on known strong UV sources. This survey would provide a basis for selecting area for detailed studies by larger, more sophisticated instruments.

Man will be utilized in star field identification, manual pointing of the UV instruments, and in film retrieval. In each of these areas man's contribution will be evaluated to determine his potential usefulness in future endeavors.

5. COMPONENT EXPERIMENTS

a. Scientific Experiments

1. UV Photographic Survey

2. Far UV Spectrometry (Image Converter)

3. Ultraviolet Stellar (Film Planchettes)

b. Support Components

1. Orientable stabilized platform

2. Maurer Star Field Camera

3. Lyman α monitor

4. Television Monitoring System

6. DESCRIPTION

This package consists of the three scientific experiments and support equipment mounted on an orientable stabilized platform. The stabilized platform will be oriented to a desired source or field and the instruments automatically sequenced for proper exposures. The platform will provide 0.01°/15 min exposure stability from a base of 10 arc min provided by an OWS. A closed circuit television system is provided for astronaut confirmation of ultraviolet platform targeting. A visible light vidicon television camera is mounted on theultraviolet platform is bore-sighted with the ultraviolet experiments. A 5-inch-diameter television display with 1.2 seconds of arc resolution is used by the astronaut for star field observation to assure that the platform is on target before beginning an experiment exposure sequence.

7. SPECIAL CONSIDERATIONS

Orbital Inclination - 28.5°-50°

Altitude - 200-300 N. M

Stabilization - $\pm$ 10 arc min from base system.
0.01° provided by experiment platform.

Pointing - $\pm 0.5^{\circ}$ provided by the platform.
The OWS will NOT require reorientation for different targets. The Platform would be mounted on a swing-out boom with 2 degrees of freedom for orientation.

Data Return - 32 lbs. film/56 day mission
Approx. 20 cubic feet

Size Power - 24 watts peak
160 watts peak

Weight - 560 pounds (including all experiments)

Film - Radiation sensitive - EVA required approx. every 5 days (or scientific airlock required)

Crew Time - Monitor - 2 min/20 min sequence
Manual Control - 1 hour/day as required - To be Determined from first data.

8. COST

Total FPE - 20.1

FY '70 - 0.100

FY '71 - 5.0

FY '72 -10.0

FY '73 - 4.0

FY '74 - 1.0

The platform prototype is currently being developed. The experiment prototypes have been built and/or Aerobee flown. The total package could be ready for flight 30 months from receiving development money.

EXPERIMENT DATA SHEET

U.V. PHOTOGRAPHIC SURVEY

1. SPECIFIC OBJECTIVE

The purpose of this experiment is to obtain photographic records of star fields and emission regions taken in ultraviolet light from 3000 Å to 1700 Å. Filtering methods require that one camera work in a near ultraviolet band 2300 Å to 2900 Å, while the second works the middle ultraviolet, 1700 Å to 2100 Å. One of the three exposures in each band is taken of the full bandwidth for fairly deep penetration in the continuum survey. A second exposure of each camera is restricted to a fairly narrow band on the emission lines from 2800 Å to 1909 Å. The third exposure of each camera will take a restricted portion of the main band, excluding or minimizing the emission lines. The third exposure will broaden the continuum reference base and provide a comparison band for the emission line.

The primary emission features to be studies are the Mg II doublet at 2800 Å and the C-III intersystem line at 1909 Å. The stellar continuum observations will enable the ultraviolet energy distribution of a large number of stars of spectral type F or earlier to be examined and will also give a general classification scheme based upon image photometry. The film will be calibrated during exposure so a moderate degree of photometric capability will exist.

2. GENERAL DESCRIPTION

The camera system consists of twin 6-inch ultraviolet cameras, together with a small wide-angle 16-millimeter camera for back-up identification and analysis of the star field in the visible region of the spectrum. All

three cameras would be mounted on a stable platform, with other UV experiments, to provide the necessary stability during an exposure sequence. Stellar images are returned on 35-mm film.

3. Operation Constraints

Orbit inclination - 28.5° - 50°

Altitude - 200 - 300 N.M.

Stabilization - 0.01° for 15 minutes

Pointing - $\pm 0.5^\circ$ to a large area of the celestial sphere without cluster reorientation.

Note: The stabilization and pointing capability will be provided by the associated stabilized platform.

4. Mode of Operation

This experiment defines two modes of operation

- Automatic, in which the system photographs random fields determined by spacecraft attitude as a function of time
- Semiautomatic, in which, with minimal astronaut participation, selected specific fields are photographed

For the selected field program the sky has been divided uniformly into fields on 4-degree centers. These fields are then divided into five priority classes.

- Priority I: 100 highest priority fields including 50 on special centers
- Priority II: 100 second priority fields
- Priority III: A coarse grid of fields covering the sky (about 600 fields)
- Priority IV: Remaining fields within 15 degrees of the galactic plane (about 450 fields)
- Priority V: All remaining fields (about 1300 fields).

The experiment could operate detached from a manned OWS if film retrieval is accomplished during periodic re-docking. However, with the stabilized platform there appears to be little reason for detaching (except for contamination to U.V. optics).

5. Crew Support

    Monitor - 2 min/20 minute sequence

    Manual Operation - Approx. 1 hour/day as required - to be determined after initial operation.

    Film Retrieval - Approx. once every 5 days. - Approx. 1/2 day for EVA if scientific airlock not provided.

    Crew Skills - No special requirements. Pre-flight training adequate

6. Spacecraft Support

    Weight - 179 pounds

    Power - 20 watts average

    Size - 21 inches long 10 inches diam. (each, 2 camera total)

    Telemetry - Housekeeping Only - Scientific Data on Film (20# total)

7. Development Schedule

    Engineering Model built

    Flight Hardware - 20 months from program go-ahead, plus

    Payload Integration - 10 months.

8. Costs

    Cost information included in the U.V. experiments package, FPE # IV.

EXPERIMENT DATA SHEET

FAR U.V. SPECTROGRAPH (IMAGE CONVERTER)

1. SPECIFIC OBJECTIVE

The purpose of this experiment is to obtain spectral and photometric data in the far ultraviolet range (1230 Å to 1800 Å) by means of wide-angle sky surveys using electronographic techniques. This experiment will allow the determination of the far-ultraviolet brightness and spectral distributions of a large number of early-type stars and will permit the determination of the accuracy with which the far-ultraviolet emission of a star can be predicted from its spectral classification and absolute magnitude. It will also help to determine effective temperatures, chemical compositions, and sources of opacity in early-type stars. Quantitative measurements of the absorbing properties, composition, density, distribution, and temperatures of gases composing the interstellar medium, including galactic nebulae, can also be made.

2. DESCRIPTION

The spectrograph is a Schmidt-type electronic image converter with objective grating. The data will be recorded on a nuclear emulsion film, Housekeeping functions will be telemetered. The instrument will be mounted on the U.V. platform and operated in conjunction with the other U.V. experiments on board.

3. OPERATION CONSTRAINTS

See FPE # IV

4. MODE OF OPERATION

See FPE # IV

5. CREW SUPPORT

See FPE # IV

6. Spacecraft Support

Weight - 62.2 pounds

Power - 2 watts average
20 watts max.

Size - 25X17X9 inches

Data - On film
Hskp. - Telemetered

7. Development Schedule

Basically the same instrument has flown on Aerobees. A unit for orbital flight could be ready in approximately 30 months, including integration time.

8. Costs

See FPE # IV

EXPERIMENT DATA SHEET

ULTRAVIOLET STELLAR SPECTROMETRY (FILM PLANCHETTES)

1. SPECIFIC OBJECTIVES

The purpose of this experiments is to record ultraviolet emissions from stars down to sixth magnitude in wavelength ranges from 900 Å to 1800 Å. Analysis of the data should add significantly to the understanding of stellar atmospheres, particularly the hotter ones from which the Earth's atmosphere absorbs the maximim emission frequencies.

2. GENERAL DESCRIPTION

The spectrograph is an all-reflective instrument with an objective grating and LiF coated optics mounted on a stable platform. A small ion chamber is included to monitor the local Lyman α flux.

3. OPERATION CONSTRAINTS

See FPE # IV.

4. MODE OF OPERATION

See FPE # IV.

5. CREW SUPPORT

See FPE # IV.

6. SPACECRAFT SUPPORT

Weight -- 70 pounds

Power -- 0.5 watt average
56 watts peak
Size - 12 inches diameter
29 inches long

Data - Science on Film Planchettes. Housekeeping - Telemetered

7. DEVELOPMENT SCHEDULE

A similar instrument has flown on Aerobees. Some re-design will be required for orbital.flight. This design and development would require

approximately 30 months to produce flight qualified hardware.

8. COSTS

See FPE # IV.

FUNCTIONAL PROGRAM ELEMENT V

HI ENERGY STELLAR SURVEY A

1. DISCIPLINE - Astronomy
2. PROGRAM ELEMENT - High Energy Survey A Stellar Astronomy
3. REQUIREMENTS
   a) Measure angular dimensions, intensity, and location of selected X-ray and Y-ray sources.
   b) Perform a sky survey to search for new X-ray and γ-ray sources.
   c) Assess man's capability to perform useful support to X-ray and γ-ray astronomy in space.
4. JUSTIFICATION

These experiments will be the first attempt to utilize man for stellar X-ray and γ-ray astronomy. However, the knowledge gained from ATM-A manned operation will be utilized to the fullest extent possible. This program element will be significant in obtaining data in any quantity on stellar X-ray and γ-ray sources. The data can immediately be analyzed by the astronomical community for the scientific results. This information can then be utilized to shape the scientific program for the grazing-incidence X-ray telescope to follow. Man will be utilized for maintenance and repair to assure that the desired long viewing times are achieved. The technology gained in flying these X-ray and γ-ray experiments will be utilized in developing more sophisticated experiments for detailed investigation.

5. COMPONENT EXPERIMENTS

a) Large Area X-ray Detector

b) Low-Energy Gamma-Ray Detector

c) Medium-Energy Gamma-Ray Detector

6. DESCRIPTION

These experiments can be accomplished by being integrated into a large manned spacecraft such as an advanced OWS, but they will need independent pointing. The large area detector array consists of proportional counters mounted on panels which have freedom to survey the celestial sphere. This array will obtain data on X-ray sources in the energy range of 0.2-60 kev. The sensitivity of the experiment is dependent upon the total exposed detector area. This description considers 100 sq. ft., but the 1.5 x 3.0 ft. modules allows for easy deviation from this value. The minimum desired area is 50 sq. ft. These arrays will scan the celestial sphere at a 4-6^{o} per minute rate with the proportional counter outputs being pulse height analyzed to obtain energy resolution. The low and medium gamma ray detectors are scintillation counters, and could be mounted on a common orientation system. Similar desired targets and viewing times make this possible. The planned base stability of 10 arc min for the OWS would be adequate for each of these dectors.

7. SPECIAL CONSIDERATIONS

Orbital Inclination:	28.5^{o} desired
	50.0^{o} acceptable
Altitude:	200-300 N. M.

Stabilization:

Proportional Array:	$\pm 0.5^{\circ}$
γ-Ray Detectors:	$\pm$ 10 min.
Pointing:	Separate pointing for the X-ray and γ-Ray experiments are desired. Each pointing system should have a capability of one hemisphere viewing with OWS reorientation.
Crew Time:	Intermittent monitoring--10 min/2 hrs. for target acquisition and setting scanning sequence.
Launch:	Integrated into OWS
Total Weight:	5200 pounds
Size:	
Large Array -	1 ft. x 100 sq. ft. (length/width open)
γ-Ray Detectors -	31" x 22" x 19" (Both)
Data:	5.2 k/bit sec
Power:	248 watts (average & maximum)

8. COST - $5.5 M (3 yr. distribution)

Flight hardware could be qualified and integrated within 36 months of receiving development money. All three experiments have undergone extensive definition and testing for the past two years.

EXPERIMENT DATA SHEET

LARGE-AREA X-RAY DETECTOR

1. SPECIFIC OBJECTIVES

The scientific objectives of the experiment are as follows:

- To locate all X-ray sources of wavelengths between 0.2 and 50 Å and of intensity greater than 5×10^{-12} erg cm^{-2} sec^{-1} over the accessible portions of the celestial sphere.
- To locate 50 of the brighter X-ray sources to an accuracy of ±1 arc minutes so as to permit ground identification with optical and radio objects.
- To determine the X-ray spectra of an estimated 100 sources, including some extragalactic sources, over an energy range from 0.2 to 60 keV. The accuracy should be adequate to distinguish thermal from various nonthermal spectral forms, and to define effective temperatures and spectral indices or the appropriate parameters to ± 20 percent.
- To determine column thickness of absorbing material between Earth and many of the detected X-ray sources.
- To determine the existence of any exceptional far-ultraviolet brightness that may be associated with particular X-ray sources
- To determine the character of short- and medium-term temporal time fluctuations of the brighter X-ray sources.

2. GENERAL DESCRIPTION:

The primary detection apparatus on which the proposal is based consists of a set of fully anti-coincidence guarded, collimated proportional counters of about 100 ft^2 frontal area. The total detection system is made up of individual modules each containing two soft X-ray counters of 4 to 5 ft^2 of window area. Currently designed soft X-ray counters have an active volume of 1.5 feet by 3 feet by 1 inch and are equipped with 1/8 mil Mylar windows and are filled with 10 percent methane, 90 percent argon at 1-atmosphere absolute pressure. The thin window is held in position, despite the large forces pushing it outward, by a honeycomb plate, which is in turn supported by heavy ribs. The gas in the thin-window counter is supplied from a small reservoir, from which a slow replacement flow is occasionally or continuously drawn. It is planned to back the soft X-ray counters by an assembly of sealed-off Xenon proportional counters, for hard X-rays, to provide useful spectral sensitivity up to photon energies of 50 ke V. Anti-coincidence guarding is effected by plastic scintillation counter protection on five sides. For the hard X-ray counters, anti-coincidence with soft X-ray counters can provide sixth-side protection, if such is beneficial. A simplified version of the system could use only the soft X-ray counters, providing 0.25 to 20 keV sensitivity. Periodic in-flight radioactive source calibration is planned.

The most desirable spacecraft configuration is that in which all

counters point in the same direction; however, splitting of the assembly is tolerable, if only by such splitting can the required total counter area be carried. If the assembly is split, it is better to have the sections point within 90 degrees of each other, than for them to point back-to-back.

3. OPERATIONAL CONSTRAINTS:

The program is being made as automatic as possible to minimize the demand on crew time for the operation. The semiautomatic concept is believed important, even for the manned laboratory formulation, because it is felt that astronauts will be very busy, and that their time can be best spent in studies that do not lend themselves to automation. The astronaut's role in the currently conceived study is that of:

- Providing initial orientation of the scan system axis
- Turning on the equipment
- Evaluating in accordance with simple predetermined guidelines the initial operation of the system

Also see Functional Program Element - V.

4. MODE OF OPERATION:

Once the search program has been initiated, operational checks by an astronaut every few orbits might be desirable. After one-half of the celestial sphere has been mapped (i.e., possible after 60 hours), a major reorienting of the scan platform is required (again a function assigned to the astronaut).

The mapping program is accomplished by mounting all the modules on a platform which is successively oriented so as to scan the celestial sphere. The type of scan to be used is a stepped spiral scan, in which a reference axis (the axis of scan rotation) is kept accurately oriented toward a fixed position in the sky, e.g., due north or directly toward the North Star. The normal to the mounting platform is maintained at a fixed "latitude" angle relative to this reference axis, while being driven at a steady angular rate "in longitude" along a constant "latitude" circle.

Precise orientation data on each module are furnished by an optical aspect system in which the signal produced by focused or collimated starlight provides a time index of the passage of the scan plane across a star. Use of stellar aspect systems with different spectral bands on different modules will permit identification of stellar class, thereby aiding in stellar identification.

Also see Functional Program Element - V.

5. CREW SUPPORT:

See Functional Program Element - V.

6. SPACECRAFT SUPPORT:

The engineering interface data are as follows:

- Weight: Approximately 4800 lbs
- Volume: 9.0 ft^3 for modules
- Dimensions: 12 modules each comprising two detectors; 18" X 36" X 1" each

- Power:

  Standby 100 watts

  Average 180 watts

  Maximum 220 watts

- Pointing accuracy: Need to determine attitude to ±15 arc minutes at any position of platform

- Stability: Not applicable (scanning)

- Thermal constraints: -18°C to 60°C (operational)

- Data: 3200 bits/sec

7. DEVELOPMENT SCHEDULE:

Single module is scheduled for balloon flight. Orbital flight hardware could be ready, qualified and integrated in 36 months.

8. COSTS:

Total - 3.0 M

FY 69 - 0.1 FY 70 - 0.5 FY 71 - 1.5 FY 72 - 0.9

EXPERIMENTAL DATA SHEET

Low-Energy Gamma-Ray Sky Survey

1. SCIENTIFIC OBJECTIVE

The scientific objective for this experiment is to conduct a general sky survey of the celestial sphere for photons in the 15 to 300 keV range. The detector will measure the flux, the spectrum, and the arrival directions of these measurements will yield information of benefit in the explanation of several new astrophysical problems

- Details of the radiation level from the collision of energetic electrons with starlight photons
- Determination of the origin of radiation in the 4 to 100 keV range from the galactic center.

2. GENERAL DESCRIPTION

The current design for the detector is as follows. A cesium iodide crystal serves as the basic detector; another cesium iodide crystal encloses the first crystal and serves as the anticoincident system. Photo-multipliers view the reactions of the crystals with photons and charged particles. The logic circuitry then permits the gamma-ray induced pulses into the proper channel of the 128-channel pulse-height analyzer.

Both crystals are of thallium-activated cesium iodide, and the front of the shield is made with 80 collimating holes that will limit the field of view of the detector to

1-degree 22-minute half angle and 63 cm^2 sensitive area. In addition the light from the central crystal is "piped" via an indirect path through the walls of the anticoincidence shield.

3. OPERATIONAL CONSTRAINTS

See Functional Program Element V.

4. MODE OF OPERATION

The apparatus is turned on and operates continuously (except perhaps in the South Atlantic Anomaly). Observations on specific sources for up to 2 hours viewing time and sky scans at rates of 1 to 1.5 deg/hr are conducted; pulses occurring in the photomultipliers as a result of gamma-ray photons entering the detector are routed to the pulse-height analyzer, and the data from this are telemetered to Earth.

5. CREW SUPPORT

Astronauts will be required for calibration once a week, also for repair and maintenance as required.

6. SPACECRAFT SUPPORT

The engineering interface data for this experiment are as follows:

- Weight
  - Δ Launch: 200 pounds
  - Δ Return: 0 pounds

- ° Volume
  - Δ Launch: 6.2 ft^3
  - Δ Return: 0 ft^3
- o Dimensions
  - Δ Spectrometer unit: 22" x 22" x 18.5" (5.2 ft^3)
  - Δ Electronics unit: flexible (1.9 ft^3)
- o Power
  - Δ Average: 18 watts
  - Δ Maximum: 18 watts
- o Telemetry: Digital = 1 kbit/sec preferred (0.5 kbit/sec could possibly be eliminated)
- o Minimum field of view: ±2 degrees
- ° Pointing accuracy: ±0.1 degree preferred, ±0.5 degree acceptable
- o Thermal constraints

  Stored: -30 to 45°C

  Operational: -20 to 35°C (prefer +10°C).

7. <u>DEVELOPMENT SCHEDULE</u>

After definition, a flight unit could be ready for integration 16 months after receiving development money. The instrument is now in final definition, but money will be required for further balloon flights to finalize and verify the detector design.

8. COSTS

Total - $844K

FY 70	$140K	FY 71	$480K	FY 72	$224K

Note: If the program slips a year from this schedule it could cost an extra $100K, but could be money well spent in design refinement.

EXPERIMENT DATA SHEET

GAMMA-RAY SPECTROSCOPY

1. SPECIFIC OBJECTIVE - Conduct general sky surveys in the 0.3 to 10 MeV energy range.

2. GENERAL DESCRIPTION - The inner crystal of the anticoincidence gamma-ray telescope will be a NaI(Tl). The active shield will probably be CsI(Tl) which has mechanical properties superior to NaI(Tl). Ruggedized photomultiplier tubes of appropriate diameters are available for the system and the active x-ray shield. The gamma-ray spectrometer is 25.5 inches in length and 9.5 inches in diameter.

3. OPERATIONAL CONSTRAINTS - See Functional Program Element V.

4. MODE OF OPERATION - See Functional Program Element V.

5. CREW SUPPORT - See Functional Program Element V.

6. SPACECRAFT SUPPORT

Weight (lbs.)	210
Power (watts)	10
Telemetry (bits/sec.)	1000
Pointing (deg.)	$\pm$ 0.5

7. DEVELOPMENT SCHEDULE - Total time from go-ahead to launch 30 months.

8. COST - Total experiment cost $1.5 million.

FUNCTIONAL PROGRAM ELEMENT VI

HI ENERGY STELLAR SURVEY B

1. DISCIPLINE - Astronomy.

2. PROGRAM ELEMENT - High Energy B Stellar Astronomy.

3. REQUIREMENT

a) To measure the flux, direction, and energy of high-energy radiation from .1 KeV up to the BeV range.

b) Provide technology for more advanced high-energy astronomy systems.

c) Determine man's usefulness in performing high-energy astronomy in space.

4. JUSTIFICATION

This package of instruments will greatly advance the state-of-the-art technology in high-energy astronomy. It will be a new dimension in man's attempt at performing any high-energy astronomy. The results will be significant in determining the future role of gamma-ray and X-ray astronomy in space and the degree of manned involvement. The technology development will be utilized in designing more sophisticated instruments for detailed selective studies. Man will be utilized for maintenance to assure that the large total viewing time is achieved.

5. COMPONENT EXPERIMENTS

a) Nuclear Gamma-Ray Spectrometer

b) Spark Chamber (Hi-Energy Gammas)

c) Gas Cerenkov Detector or Ionization Calorimeter

d) X-Ray Spectroscopy

6. DESCRIPTION

The group of experiments composing this Functional Program Element (but not an individual package) could be integrated into the OWS design, or if desirable they could be packaged in an ATM-type rack and hand-docked' to the OWS for operation. The X-ray spectroscopy experiment should be on an orientable boom with independent pointing and capability. The Nuclear Gamma-Ray Spectrometer (weighing approximately 5000 lbs. and requiring viewing times of up to two weeks on one source) should be gimbaled to the OWS to allow individual pointing without affecting cluster orientation or the pointing of other experiments (The Spark Chamber could be combined within this gimbaled system as targets and viewing times are similar). The Gas Cerenkov Detector, being approximately 20 ft. long and 12 ft. wide, should be integrated into the OWS. The desired energy range (500 MeV) is sufficiently high to allow viewing through the side wall of the OWS. And the instrument is short enough to permit the cross mounting. If this proves undesirable when considering OWS design and operational constraints, then this gas cerenkov detector could be considered for an independent fly-away module.

7. SPECIAL CONSIDERATIONS

Orbital Inclination:	28.5° desired
	50° acceptable
Altitude:	200-300 N. M.
Stabilization:	$\pm 0.5^{\circ}$ acceptable (Additional requirement provided by experiment)

Pointing:	$\pm$ 0.5° acceptable. Pointing capability independent of the spacecraft with approximately 1 hemisphere viewing desired.
Crew Time:	Intermittent monitoring. Approximately 5 min./2 hours required for target acquisition.
Launch:	To the extent possible, all instruments should be integrated into the OWS and launched with it. (One possible exception would be the Gas Cerenkov Detector.)
Total Weight:	8000 lbs. approximately
Size:	See individual experiment data sheets.
Power:	580 watts peak 460 watts average
Data:	7.2 k bits/sec acceptable 11.2 k bits/sec. desirable

8. COST

Total (4 experiments) - Approximately 17.5 M

Normal distribution for 5 year development period.

EXPERIMENT DATA SHEET

NUCLEAR GAMMA-RAY SPECTROMETER

1. SCIENTIFIC OBJECTIVES

   a. To search for predicted monoenergetic gamma-rays resulting from radioactive decay of elements in supernova remnants, particularly the Crab Nebula.

   b. To obtain the probable by-product of the experiment which should be information on the spectrum shape for energies between 50 and 600 keV of the X-ray continum from several X-ray sources (the same ones examined for presence of radioactivity).

   c. To attempt to observe annihilation quanta (energy = 0.511 MeV) from several potential sources and neutron - proton capture gamma-rays (energy = 2.225 MeV) from the Sun.

2. GENERAL DESCRIPTION

The Ge(Li) detector crystals will be 1-inch by 1-inch cross section and either 1.5 or 3 inches in length, depending on experience to be gained in "breadboard" production. Cryogenic cooling is necessary.

The electronics for the experiment, including an analog-digital convertor of several hundred channels and a pulse height analyzer, are under development or already exist, though they must be space hardened to satisfy conditions for the proposed experiment.

A cryostat for close packing of the detector array has been designed

with special attention paid to:

- Low heat loss
- Low gm cm^{-2} across the entrance window
- Mechanical integrity enhanced to withstand a launch environment.

The shielding proposed was designed to reduce the background count rate from all directions, other than the aperture, to equal the rate that would be caused by photons coming down the aperture for a random aperture orientation. It consists of a thick plastic scintillator and a bismuth/epoxy resin compound coated internally with copper.

3. OPERATIONAL CONSTRAINTS - See FPE # VI.
4. MODE OF OPERATION - See FPE # VI.
5. CREW SUPPORT - See FPE # VI.
6. SPACECRAFT SUPPORT

Weight (lbs)	5000
Power (watts) avg/max	250/250
Volume (ft^3)	60
Telemetry	3-7 K bits/sec
Pointing deg	± 0.5

7. DEVELOPMENT SCHEDULE

The basic hardware is currently int the balloon flight phase and will continue so for the next two years. Following the balloon flights, about three years would be required to launch.

8. COST - Total cost $5.75 M

EXPERIMENTAL DATA SHEET

HIGH-ENERGY GAMMA-RAY ASTRONOMY SPARK CHAMBER DETECTION SYSTEM

1. SPECIFIC OBJECTIVES

a. To locate precisely in direction (within 0.5 degree or less) any cosmic sources of gamma rays of energy 30 MeV and flux greater than $1X10^{-7}/cm^2$-sec. This involves a random sky survey with continuous observation, plus the possibility of looking at specific celestial postions.

b. To measure the flux (number/cm^{-2}-sec) of at least several such high-energy groups of photons, provided the fluxes exceed $1X10^7$ cm^{-2}-sec, approximately.

c. To investigate the background (flux and isotropy) of photons and charged particles for regions of the sky where no "point" sources of high energy are found.

2. GENERAL DESCRIPTION

a. Equipment

The spark chamber detection system consists of four packages:

- Package No. 1: Package No. 1 consists of the high-energy gamma ray and charged particle detector. The high-energy photons are detected indirectly by direct detection of the electron pairs produced by photon conversion. The heart detection system consists of a spark chamber array consisting of alternate layers of thin wire, two-dimensional grids,

scintillators, an energy measuring device, and possibly a gas Cerenkov detector and nuclear emulsions.

The weight of this package will be about 600 to 800 lbs.

- Package No. 2: Package No. 2 consists of the electronics associated with the detector (Package No. 1). The essential electronics will be compactly integrated into the detector to minimize lengths of conductors. It is designed as a separate package for logic purposes. The electronic package is a 13-inch cube (approximately) and weighs 15 to 20 lbs.
- Package No. 3: Package No. 3 consists of the console for handling displays, housekeeping information, control for the detection system, data storage, and telemetry interface. The console is a square prism with approximate dimensions of 24 by 24 by 13 inches and weighs 10 to 50 lbs.
- Package No. 4: If nuclear emulsions are included, a radiation-shielding box for storage of the photographic emulsion will be required. The radiation shield may be adjacent to the detector (Package No. 1) or in other locations. This package is a cylinder approximately 40 inches long by 40 inches in diameter and weighs 500 to 1,500 lbs. The emulsion pack will require a replacement by a second pack or by a radiation converter at the conclusion of each 14-day period.

b. Operation

Suspected point sources of cosmic gamma rays will be investigated. A minimum pointing time (in one direction, for each suspected point source being examined) of 1/2 to 7 days is required (cumulative time; continuous observation is not required). A sensitivity threshold of 10^{-7} photons/cm^2-sec is expected.

During times when a fixed pointing direction is not maintained, the detectors will scan the whole sky so observing any unknown point sources visible above background and also measuring the background.

If nuclear emulsions are used, it is estimated that the emulsion pack will be useful for a maximum exposure time of 10 to 14 days at which time the pack must be removed (requiring EVA by astronaut) and replaced by a second pack or by an inactive photon-electron pair converter thus terminating observations via emulsions. It is hoped that two emulsion packs can be expected, each for 10 to 14 days.

The spark chamber would be in automatic operation continuously for about 1 or 2 years. Data will be acquired at the rate of about 10^3 bits/second. This data cannot be substantially reduced by on-board data processing; so the spacecraft must telemeter about $5X10^6$ bits/orbit.

3. OPERATIONAL CONSTRAINTS

See FPE # VI.

4. MODE OF OPERATION

See FPE # VI.

5. CREW SUPPORT

See FPE #VI.

6. SPACECRAFT SUPPORT

The engineering interface data for this experiment are as follows:

- Weight

  Minimum: 1000 pounds
  depending primarily on shielding
  Maximum: 200 pounds

- Dimensions: Detector: 50" diam x 99" long

  Standby 106 watts

  Average: 146 watts   for other versions 30 watts is ample

  Maximum: 241 watts

- Pointing accuracy ±0.3 degree

- Stability: None specified

- Thermal constraints

Detector:	- 20° C to + 55°C	
Electronics:	- 15° C to + 50°C	Operational
*Emulsions:	+ 15°C to + 55°C	
Detector:	- 20°C to + 55°C	
Electronics:	- 25°C to + 70°C	

*Emulsions: - 15°C to + 25°C

*Only if used

- Low earth orbit
- Man required for checkout, ortientation and emulsion replacement.

7. DEVELOPMENT SCHEDULE

Developed in 3 years if funded at rate of 300K/year. Spacecraft hardware in two years.

8. COSTS

Total 2M.

EXPERIMENT DATA SHEET

LARGE-AREA GAS CERENKOV DETECTOR

1. SPECIFIC OBJECTIVES

   a. To search for discrete sources of cosmic gamma rays, such as those expected in the Crab Nebula and in M87.

   b. The detector will be used in Earth orbit and later on the lunar surface to identify discrete sources of various signal strengths.

   c. In each case measurements of flux, energy spectra, and arrival directions of gamma rays will be obtained.

2. GENERAL DESCRIPTION

The detector will consist essentially of a slab of converter (a high-Z material), a tub filled with an appropriate gas (e.g., Freon 12), a mirror and a small array of photomultiplier tubes (see Figure 2).

A gamma-ray photon entering the converter will produce a positron-electron pair, and these particles will have sufficient velocity to cause the emission of Cerenkov radiation in the gas filling the tube. This visible Cerenkov light is emitted in a narrow cone and thus strikes the mirror at the far end of the tube; it is then focused back to the photomultiplier array where the resulting pulse is recorded and hence the gamma-ray photon is counted.

Various anticoincidence and scintillation counters are also strategically positioned in the tube and their outputs integrated into the recording mechanism in order to provide discrimination against spurious pulses which would otherwise result from neutrons or various charged particles (e.g., protons) entering the detector. The gas container is a cylinder approximately 20 feet long and 9 feet in diameter, constructed of aluminum of fiberglass if rigid, silicone rubber if collapsible. Alternative gas container could be a flexible glass-cloth envelope that encloses the entire detector, of which there is a commercially available model.

3. OPERATIONAL CONSTRAINTS

If the S-IVB stage is launched "dry," the Cerenkov detector can be installed prior to launch, thus greatly simplifying the experiment. The astronaut would then only be needed for maintenace of the detector.

Counting rates and other data (e.g., aspect, temperature, pressure, etc.) would be multiplexed and transmitted to the ground via a 6-watt transmitter operating at 1 490 MHz.

Also see FPE # VI.

4. MODES OF OPERATION - SEE FPE # VI.

5. CREW SUPPORT

Crew support will be limited to monitoring and maintenance.

6. SPACECRAFT SUPPORT

The engineering interface data are as follows:

Weight: 1,200 lbs

Volume: 2,263 ft^3

EXPERIMENT DATA SHEET

X-RAY SPECTROSCOPY

1. SPECIFIC OBJECTIVES

To obtain absolute measurements, to an energy resolution of 1 percent or better, of the flux of 0.1 to 8 keV photons emitted by known and potential cosmic x-ray sources, and portions of solar streamers. Emphasis here is on determining the thermal or nonthermal nature of the x-ray emission from these objects by searching for and evaluating evidence for bound-bound, free-bound, and free-free transitions.

2. GENERAL DESCRIPTION - The instrument consists of a special diffraction grating for dispersing x-rays combined with a venetian blind focussing device to correct the dispersed x-rays into a line image. A 3-meter-long instrument might have an effective aperture of $\sim 0.1\ cm^2$ at an x-ray energy of 2 keV for each of the spectra , a total of four such apertures being obtainable for the particular configuration shown. The data will either be stored on conventional fast film or passed through a television-like system, digitized and stored on magnetic film for later transmission to ground. For a greater understanding of the data from the spectrograph at least two gas-proportional counters would be used to monitor the source's x-ray flux during an exposure.

3. OPERATIONAL CONSTRAINTS - See Functional Program Element VI.

4. MODE OF OPERATION - See Functional Program Element VI.

5. CREW SUPPORT - See Functional Program Element VI.

6. SPACECRAFT SUPPORT

Weight (lb.)	800
Power (watts) Avg./max.	20/30
Volume (ft^3) 40 (stored)	60 ft^3 (operating)
Telemetry	200 bits/sec.
Pointing	$\pm$ 0.5 arc minute

7. DEVELOPMENT SCHEDULE

From design initiation to flight will require about five years.

8. COST

FUNCTIONAL PROGRAM ELEMENT VII

ADVANCED UV STELLAR

1. DISCIPLINE - Astronomy

2. PROGRAM ELEMENT

Advanced UV Stellar - 3 Meter Diffraction-Limited Optical Telescope Program.

3. REQUIREMENT

To investigate planets, stars and galaxies to resolve burning questions about our solar system, galaxy, and universe (e.g., what are the evolutionary processes of our universe?). A 3 meter diffraction limited reflector telescope capable of providing .06 arc-second resolution is required. It must allow for attachment of various instruments provided by several investigators; be capable of remote operation in response to ground control; and be designed to enable long-term maintenance and replacement of component parts or instrument packages for updating.

4. JUSTIFICATION

Diffraction-limited images from a large space telescope (LST) can provide significant increase in our knowledge of the spatial structure of astronomical objects in our solar system, galaxy, and universe and permit the detection of fainter objects than presently possible from the ground to the limit of our universe because of the increased angular resolution. It will also allow higher stellar spectral resolution to be produced more efficiently by instruments employing dispersive optical systems. In designing a large 3-meter diffraction-limited telescope,

information derived from a smaller (in cost and technical magnitude) 2 meter man-maintained telescope or information from a precursory 3-meter flight to establish technology should be available. Both manned operations capability and optical technology must be advanced before and during the development of a precursor flight telescope in order to prepare for the National Astronomical Space Observatory (NASO) 3-meter telescope. Manned operations will include controlling the docking, initial start-up and data acquisition. Man will also participate in the replacement of out-dated components or instrument modules, a concept considered essential in the successful operation of the projected 10 yr. life of the NASO 3-meter telescope facility. Stabilization and guidance systems more sophisticated than those yet available from present technology must be developed for and tried out by the precursory telescope flight.

5. <u>COMPONENT EXPERIMENTS</u>

a) 2 meter diffraction-limited or 3 meter telescope (initial flight), 3 meter diffraction-limited telescope (optical NASO) follow-on flight.

b) Spectrographic, photometric, and videographic instruments, which may be interchanged, replaced, or updated as needed.

6. <u>DESCRIPTION</u>

The resolution of whether the precursory flight shall be 2 meters aperture or whether an "all-up" concept to 3 meters has not been resolved. Therefore, the description of both systems is included.

6.1 2 METER TELESCOPE

The telescope has an aperture of 2-meter, a field of view of 2 arc-minutes, active internal optics for image motion correction, will provide high resolution (0.1 arc-sec.) spectrographic and imagery analysis in the range 900 Å to 10,000 Å using electronic image detection systems. For operation it will require a carrier vehicle for maintaining coarse orientation, docking, and station keeping. It will require extreme care in thermal, optical, and mechanical design; in low earth orbit the projected lifetime should be 2-5 years.

Diffraction-limited imagery presents formidable design problems since it is necessary to stabilize the field of view to a fraction of the diffraction-limited image size is about 0.05 seconds of arc for a two-meter aperture, the required guidance accuracy is about 0.01 seconds of arc. This corresponds to about 5×10^{-8} radians or one inch in 300 miles.

The most feasible method of achieving this degree of stability is to use stars within the telescope field of view as a guidance reference. Other methods, such as a separate boresighted guidance system are more difficult because of the thermoelastic deformations occuring in the entire telescope structure as the satellite sweeps in and out of the earth's shadow. With common guidance and imaging optics it is possible to achieve a very high degree of immunity to structural changes since these produce identical changes in the guidance and image fields which are indistinguishable from guidance errors and which are nulled by the guidance system. The objectives of the 2-meter telescope mission are listed below:

- Resolution of the daylight astronomy question.

- o Resolution of the low-high altitude orbit question for space telescopes.
- o Resolution of the primary mirror question.
- o Help in resolving the astronomy mission for a National Space Station Observatory.
- o Provision of space data on telescope suspensions for the next generation of less than 2-meter space telescopes.
- o Resolution of some of the manned astronomy questions including the duties and performance limits of astronauts working with large space telescopes.
- o Provision of space maintenance data in a large telescope conceived and designed from the very beginning for in-space flight maintenance.

BASIC EXPERIMENT HARDWARE:

- o Seven unique and individual mirror segments: (these may be traded-off in SRT activities)
  1. Thin deformable mirror.*
  2. Eggcrate fused quartz mirror segment made of material 7940
  3. Silicon mirror segment.
  4. Beryllium segment.
  5. Cervit mirror segment.
  6. Eggcrate fused quartz of 7971 material.
  7. Solid fused quartz mirror segment of 7940 quartz.
- o Phase-measurement interferometer for figure sensing each segment and the entire surface.
- o White-light interferometers for coarse segment alignment.*
- o Actuators to align segments to each other in response to data from figure sensor.
- o Electronic analyzer and programmer to convert data from interferometers into actuator commands.

The segments of the 2-meter mirror are located and held in position (pitch, yaw, and in-out along the optical axis) to better than 1/50 wave

by the phase-measuring interferometer functioning as a mirror figure error sensor.

The importance of developing techniques for applying astronaut operations is provided for by designing around the concept of providing flexibility to the scientific payload. The arrangement of having six identical and interchangeable instrument packages arranged behind the primary mirror permits in-flight changing of scientific instruments as well as the removal of a specific instrument module from its nominal location and servicing the instrument module in the manned space station.

The concept includes the design of important and useful scientific instruments in five of the six instrument modules. The other module contains equipment to assist in the collection of data germane to optical technology. Also, the spectrometers and image systems will be collecting engineering data on the performance of the various pointing systems in the technology experiments (transfer lens, free float, gimbals) under the various conditions of daylight and night time, coupled and uncoupled to the cluster and possibly for both low orbit and high orbit.

(* Perkin-Elmer Contract with Langley Research Center NAS1-7103)

6.1.2 UTILIZATION OF MAN

Manned Astronomy Area - Due to the long trouble free life requirement and due to the need to provide equipment flexibility in the instrument section of a large space telescope, it is an inescapable conclusion that the future large optical space observatories will be maintainable by an astronaut in space. There are three experiments directed at the utilization of man in the tending of future large orbital telescopes.

(Experiment No. 1) The astronaut utilization experiment is basically designed to learn how to support the large orbiting telescope system by having the astronaut perform two tasks:

1. Removing and replacing one of the mirror segments in the segmented optics group of the primary mirror.
2. Removing and replacing the scientific and engineering equipment modules located behind the primary mirror.

Based on data obtained from that experiment, it could be established which of the primary mirror segments has the poorest figure in the space environment, and that specific mirror segment would be replaced by a spare mirror segment which was carried aloft at the time of launch. The removal and replacement of one of the equipment modules behind the primary mirror is more complex than the initial mirror removal experiment because these units have electrical interfaces with the spacecraft and telescope as well as the close tolerances between optical and mechanical equipment.

(Experiment No. 2) Scatterplate Photographs of the Primary Mirror is too complex an operation to execute without the assistance of a specially trained astronaut. The performance of this task in the optical laboratory requires a high degree of optical know-how and dexterity. There is considerable question as to the likelihood of success of this experiment in the initial attempt. However, an important factor working for the success of this experiment is that the location at which the astronaut will conduct the experiment is at the very front of the telescope. This area is clear and unencumbered with other equipment.

(Experiment No. 3) Mirror Coating in Space requires the services of the astronaut to assist in the experiment. The mirror that is removed from

the primary in Experiment No. 1 can be transferred to a mirror recoating tank by the astronaut. The astronaut would get it properly placed in the equipment, and after the recoating operations are completed, the mirror could be returned to the main telescope.

For a space telescope to be serviced in flight, the instrument must be designed with this intent from the very begnnning. Thus, the present state of the conceptual design is such that the primary mirror, secondary mirror, figure sensor, scientific instruments and all functioning mechanisms are arranged to that access is provided to the astronaut from outside the telescope. Also, all mechanisms and functional units are modularized so that they may be replaced with the minimum of astronaut participation in EVA.

6.1.3 DEVELOPMENT COST AND SCHEDULES

Year	1971	1972	1973	1974	1975	1976	1977	1978	1979
Cost(m)	.5	1.5	5	8	12	16	8	4	3

Total $58M (Precursory 2-meter only)

Launch Date: 1978

6.2 3-METER TELESCOPE

The telescope has an aperture of 3-meters, a field of view of 2 arc-min, active internal optics for image motion correction and will provide high resolution (.06 arc-sec) spectrographic and imagery analysis in the range 900 Å to 10 microns. For operation it will require a carrier vehicle for maintaining coarse orientation, docking, and station keeping. It too will require extreme care in thermal, optical, and mechnical design. Projected life time of 10 years or longer is expected at low earth orbit or synchronous orbit.

6.2.1 GENERAL CHARACTERISTICS

The telescope portion is a Cassegrain collector with a primary mirror of 3-m aperture and 12-m focal length, and a secondary mirror which provides the 3.75 power magnification for an effective focal length of 45 m. A field of view of 15 arc-min. is desired for some of the photographic work. Because a field of these dimensions would be helpful in locating suitable guide stars, a Ritchey-Chretien figuring of the primary and secondary reflectors is recommended in preference to the classical Cassegrainian (paraboloid-hyperboloid) type because of its wider field of view. The primary mirror will be active segmented optics design 1 utilizing seven (7) segments.

The instrumentation section for this telescope as a minimum contains a 225-mm (9-in.) plate camera to survey celestial areas rich in galaxies, a 70-mm camera, which can take 35- or 70-mm format for use where the field requirements are most modest, and a spectrograph to study the spectra of quasi-stellar sources, with particular attention to Doppler shift measurements for determination of radial velocities.

Because this telescope is planned for a later generation, the design is left flexible to incorporate instruments required to answer questions raised by observations performed in the intervening period, and other equipment made possible by advances in the technology, such as "electronographic" recording, high-resolution image intensification or video transmission. (Note: the photographic description included is to be freely interpreted to mean imagery by electronic means based upon the rapid development expected in this area.) Because it is probably not feasible to attach

a telescope as large as this to a spacecraft by means of a gimbaled suspension, provision is made for three-axis control-moment-gyro orientation control, rather than two-axis control. The excess energy stored in the gyros is dumped during periodic dockings with the manned spacecraft. These same dockings are used to service the telescope in other ways, such as photographic magazine changes and scheduled maintenance, or emergency repair. The telescope may be hard mounted to the spacecraft if sufficient s/c stabilization can be achieved.

Guidance is accomplished by star tracking systems; externally mounted star trackers are combined with integrated star tracking instrumentation that is part of the telescope optical system. The number of external trackers is sufficient to permit continuous control, despite the need to transfer from one tracker to another during slewing.

The following pages of tabular data describe in detail the physical and optical characteristics of the telescope.

6.2.2 UTILIZATION OF MAN FOR INSTRUMENTS

Deployment

Because this very large telescope is initially operated as a photographic camera, and, hence, is mechanically simple, deployment is automatically erected, and the mirror coverings and camera-protective envelopes are removed by servo-mechanisms.

Alignment

An optical technician, who observes a TV monitor screen (projected image from an autocollimator) and uses remote controls, checks and adjusts the optical alignment (tilt, centration, and focus).

Calibration

Three cameras and a spectrograph are to be calibrated. Preprogrammed sequences of standard test stars are photographed with varying exposure times through each UBV filter. More time is required for calibration of this telescope as compared to the 2-m diffraction-limited UV-visible-IR telescope because it is intended for use with fainter astronomical sources. The observer uses a microdensitometer to calibrate the spectrograms and an iris (or constant diaphragm) photometer for the photographic photometry.

6.2.3 DEVELOP COST AND SCHEDULES

The development schedule is shown in Figure 2.

6.2.4 INSTRUMENTATION SECTION

70-mm Plate Camera

The function of the 70-mm camera is to record with the highest possible resolution the images of specific objects such as galaxies, globular clusters and quasi-stellar sources in different wave length bands in order to determine their structural characteristics. To this end, a plate 70 mm format (50 mm clear, see Table VIII) has been devised. The camera provides a feed and a take-up magazine with a transport to take a plate from the feed magazine to the exposure position, and at the end of the observation, to the take-up magazine. Since a filter wheel with the required aperture would be excessively large, a similar device is used for selecting the desired filter for the observation. A plate camera is preferred to a roll film camera because it avoids the electrostatic sparking problems and other deleterious effects of film friction.

225-mm Plate Camera

For the measurement of Cepheid variable stars, as a means of

determining the distance of the galaxies in which they are located, it is helpful to photograph a reasonably large area so that many stars are recorded in a single exposure. To satisfy this requirement, a large format plate camera magazine is presented. The plate used is 225-mm square (200 mm clear, providing for a field of view of 15 arc-min. square. The camera and plate changer, magazine and filter mechanisms are enlarged versions of the 70-mm camera.

Concave Grating Spectrograph

For measuring the Doppler shift in the radiation received from quasi-stellar sources, a concave grating spectrograph is supplied. The spectrograph consists of a slit, a concave grating and a camera.

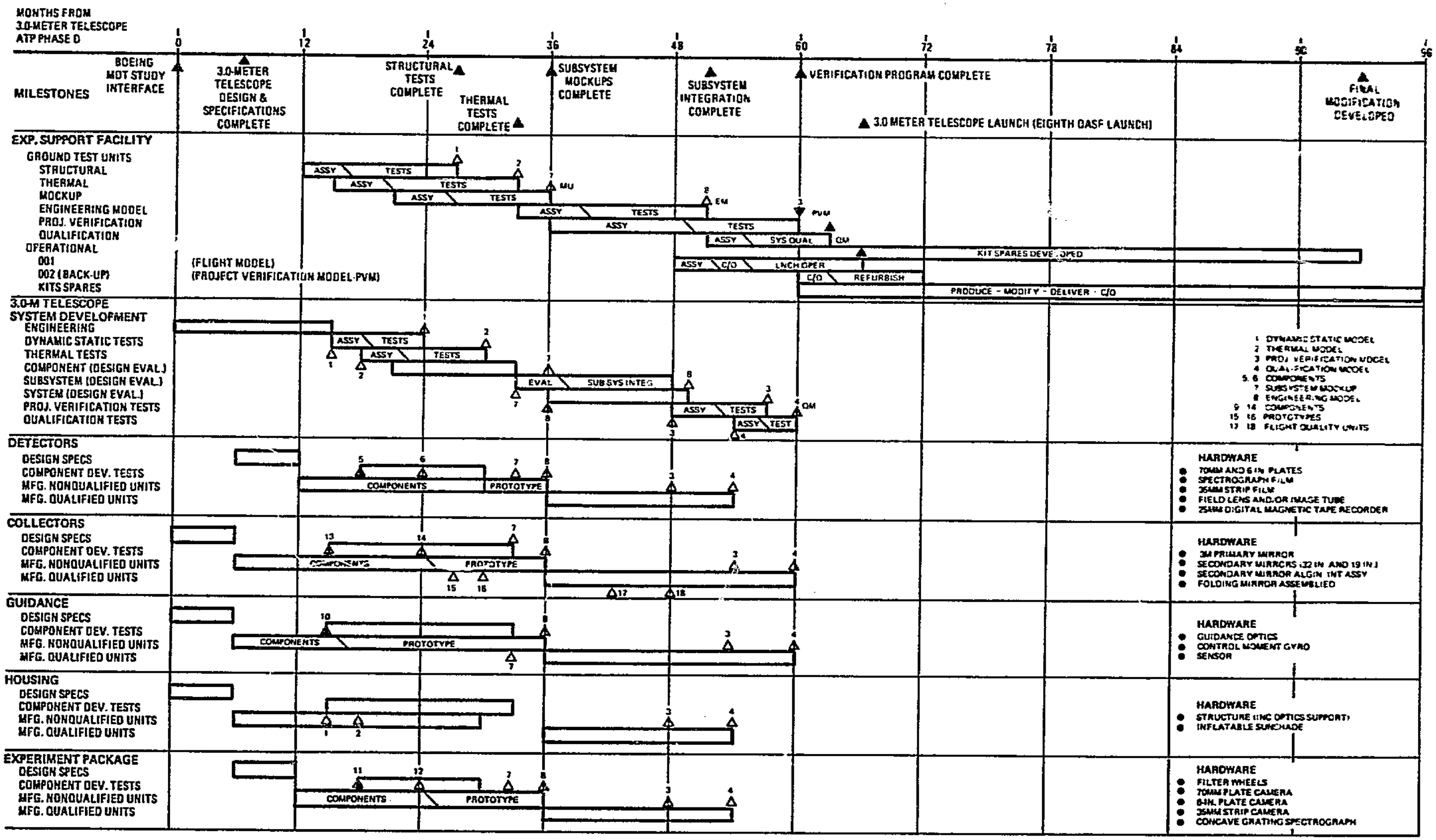


Figure 2. Development Schedule, 3-Meter Diffraction-Limited UV-Visible-IR Normal-Incidence Telescope, Stellar

FUNCTIONAL PROGRAM ELEMENT VIII

ADVANCED SOLAR

1. DICIPLINE - Astronomy
2. PROGRAM ELEMENT - Advanced Solar
3. REQUIREMENTS
   a. Conduct extremely high resolution visible and UV studies of the Solar granular structure and areas of high solar activity. Also continue the XUV and X-ray observations with higher spatial and spectral resolution using larger apertures, more efficient reflective surfaces and improved instrumentation.
   b. Man maintainable systems which are designed to take maximum advantage of man's presence. Many of these modules may operate detached from the space station.
   c. Long lifetime system capable of being efficiently and conveniently operated either from a space station or the ground. This will possibly involve the use of advanced communication satellites for realtime ground control.
4. JUSTIFICATION
   a. The dramatic influence which the Sun has on the Earth, its atmosphere and magnetic field, as well as the improved knowledge of stars which will result from solar studies, is justification for intensive solar studies.
   b. The necessity for man-maintainable systems arises from: the need for versatile telescopes which can be retrofitted with different or improved sensor systems;

longer lifetime operation, thus improving the mission success probability; and the astronaut's ability to provide routine servicing as well as assisting in conducting unique observations which require a closer association with the telescope than can be provided by the ground based observer.

c. The larger, more sophisticated telescopes will be expensive and will be operated from space stations capable of essentially indefinite life. For these reasons it is essential that they have a comparable lifetime with their orbital support equipment.

5. COMPONENT EXPERIMENTS

It is difficult at this time to make an all inclusive listing of the Advanced solar telescopes which will be appropriate for the late 1970's. The following list of telescopes is only an example of what may occur.

a. 1-1½ meter diffraction-limited UV Photoheliograph.

b. .2 - .5 meter aperture XUV spectroheliograph and spectrometer.

c. Large aperture coronagraph capable of observing out to 30 solar radii.

d. 0.5 meter aperture X-ray grazing-incidence telescope with direct imaging and spectrometer.

6. DESCRIPTION

6.1 1.5-Meter Diffraction-Limited UV-Visible Solar Telescope

6.1.1 General Characteristics

The late time-period solar telescopes are essentially larger and more refined versions of the earlier ATM instruments. This holds true for the off-axis (Herschelian)

and grazing-incidence telescopes, as well as for the Gregorian telescope described in this section. In general, the larger aperture provides increased resolution and, with its larger collecting area, permits higher linear magnification or linear dispersion with the same exposure time.

The late time-period solar telescope for the 1,500-Å and longer wavelength range is a Gregorian telescope of 1.5-m aperture and 75-m focal length. The collecting optics consist of a primary mirror of 1.5-m aperture and about 5.35-m focal length, and a secondary mirror providing about 14.0 diameters of magnification. The image is brought to a focus about 0.3-m behind the primary mirror.

The instrumentation section behind the primary mirror consists of a triple range echelle spectrograph, a slit-jaw camera, and space provision for a solar magnetograph. The solar magnetograph is a specialized instrument of which only a very few exist at present.

In the solar telescopes, guidance will mainly be inertial, with updating coming either automatically from the image of the sun's limb with or without a programmed scan, or manually from an astronaut observer viewing an image of the sun on a monitor, and endeavoring to keep a specific feature of scientific interest in the field of view or on the slit of a spectrograph. Coarse relolution can be achieved

through a modest sun sensor device.

6.2 0.25-Meter XUV Spectroheliograph Normal-Incidence Solar Telescope

6.2.1 General Characteristics

The 0.25-m XUV Spectroheliograph is a special -purpose instrument designed to record the image of the solar disk in several extreme UV wavelengths simultaneously. Because of the history associated with this instrument, and the success enjoyed by the Naval Research Laboratory in rocket flights, the spectroheliograph is based on the Naval Research Laboratory design which is proposed for the Solar ATM as part of experiment S053. This is the logical sucessor to the earlier rocket-borne instrument. The telescope has a concave grating with figure corrections to improve the image quality. The grating is plated with gold and ruled at 3,333 lines/mm. An aperture of about 0.25-m with a focal length of 3-m provides the scale factor and image brightness required.

An unbacked thin film of aluminum possesses the desired wavelength transmission range, while reflecting the much more intense visible energy. As a further protection, thermal mirrors are placed at strategic points to reflect the zero order image and the first order visible range energy back out into space through the entrance aperture. The camera consists of a magazine to store the film strips, advance them to exposure position, and return them to storage in the manner of an automatic slide changer. A shutter, operated on command, controls the exposure time.

An auxiliary telescope consisting of an objective lens of about 0.1-m aperture, a narrow bank filter, and a video camera, is boresighted to the spectroheliograph telescope, to provide the astronaut-observer with guiding information. Control gyros provide the steering torques. An automatic guidance subsystem is also entirely feasible for this telescope.

6.3 1- to 6- Solar Radii Coronagraph Normal-Incidence Telescope

6.3.1 General Characteristics

The 1- to 6-solar-radii coronagraph combines with the 5- to 30-solar-radii coronagraph to observe white-light emission of outward-moving plasma clouds from the solar limb to a distance of 30 solar radii from the center of the sun. Coverage of this considerable region is divided into two instruments for the following reasons: (1) the two instruments are each relatively small in size as contrasted with one instrument of unwieldy proportions; (2) the inner coronagraph, which requires a much smaller field of view, provides higher resolutions for a given image size, in the region where the coronal phenomena are expected to be much more interesting; (3) the range-of-response requirement for the recording medium (film) is considerably relaxed by splitting into two parts the six-to eight-order-of-magnitude difference in radiation flux levels between the solar limb and 30 solar radii.

The 1- to 6-solar radii coronagraph is a motion picture

camera with a telephoto lens to restrict the field of view to three degrees on a 35-mm format. It is fitted out with occulting disks, both internal and external to block out the direct rays of the sun so that the picture obtained contains the image of the inner corona without the glare of the direct sun. It is composed of four parts; an optical bench, which ties everything together; an optics housing, which provides a support for the objective lens, field lines, relay lens, folding mirrors, elements of the calibration chain, and thermal mirrors; a light tube, which serves as a baffle, a support for the instrument cover, and protection for the external occulting disks; and a 35-mm cine camera, which records the corona pictures on film.

Optically the coronagraph consists of an objective lens and relay systems which form an image of the corona at the camera focal plane. On the field lens, which is at the focus of the objective lens, is an internal occulting disk. This disk occupies the place where the solar image would be were it not for the external occulters. It blocks the last remnant of direct solar light. In front of the objective lens by somewhat over two meters is an external occulting disk, supported by the optical bench and so designed as to shield the internal optics completely from direct sunlight, yet offer minimum vignetting to light from the corona. Backing up this occulting disk are two more disks, placed so as to cut off any diffraction effects that would permit

sunlight to pass. A thermal mirror(f/100) surrounding the objective lens redirects unused solar radiation out into space again, protecting the instrument from undue heating.

The instrument is an outgrowth of the coronagraphs that have been operating for many years in the mountain observatories in Colorado and Southern France. It is anticipated that by going into space higher contrast and correspondingly higher definition can be achieved.

6.4 5- to 30-Solar Radii Coronagraph Normal-Incidence Telescope

6.4.1 General Characteristics

A modification of the inner coronagraph of Section 6.3 is recommended for the photographing of the outer corona. If the diameter of light tube is increased from 0.25-m to 0.65-m the objective lens will have an unobscured view out to a full field of 16^{o} or a view of the corona out to 30 solar radii. An external occulting disk was sized to provide full occultation of the inner corona. to 3 solar radii and no vignetting beyond 5 radii. The length of the light tube was retained at 2.16-m and the effective focal length of the optics was set at 90-mm to provide for a plate scale including 30^{o} in a 24-mm format. With these design criteria, a layout was perpared for a camera to record the outer corona. The camera consists of a 35-mm cine magazine with 90-mm EFL optics and an aperture of 40-mm. The focal ratio of 2.5 compared with 12.9 on the inner corona camera reduces the discrepancy in required

exposure time. The camera optics include an objective lens, a field lens with the additional occulting disks placed at strategic points in between.

The combination of the two corcnagraphs permits simulataneous recording of both inner and outer coronas. It permits each part of the corona to be recorded at an appropriate scale factor, thus taking advantage of a larger effective format to show the inner corona in more detail.

6.5 0.5 Meter X-Ray Grazing-Incidence Solar Telescope

6.5.1 Scientific Objectives

The objective of this X-ray telescope is to increase both the spectral resolving power and sensitivity by one or more orders of magnitude and to scan individually selected lines with a temporal resolution of seconds and spatial resolution approaching that available in visible light.

The experiment is designed to measure the solar X-ray spectrum (approximately 1 to 24 Å) with a spectral resolution approaching the crystal diffraction limit, a spatial resolution of a few arc-seconds and a temporal resolution of 1 second. The specific objectives of the experiment are outlined below:

1. To study the spatial distribution of temperature and density of an active region of flare, by observing the variation in line intensity and relative line width and

relative line intensities.

2. To determine the validity of the concept of thermal equilibrium, by comparison of ion and electron temperatures, derived respectively from line widths and relative intensities.

3. To observe rapid fluctuations in line intensities indicative of large-scale changes in the energy input.

4. To attempt to measure macroscopic material movements by Doppler shift measurements.

5. To observe relatively weak lines to determine the coronal abundance of elements such as Na and Al, and to study higher series members of the strong spectra for detailed comparison with theoretical predictions..

6. Determination of electron temperature and charge density in the corona at different solar latitudes, from near the Equator out to the Pole.

7. Observations to determine if there is a significant hot component in the background corona. (This could not be unambiguously studied by broad-band photography, because of the spectral proximity of lines, e.g., FeXVII and OVIII, having a quite different temperature response).

8. Observations to study possible local abundance variations, e.g., in the FE:O or NE:O ratios by comparison of the active region and coronal disc spectra.

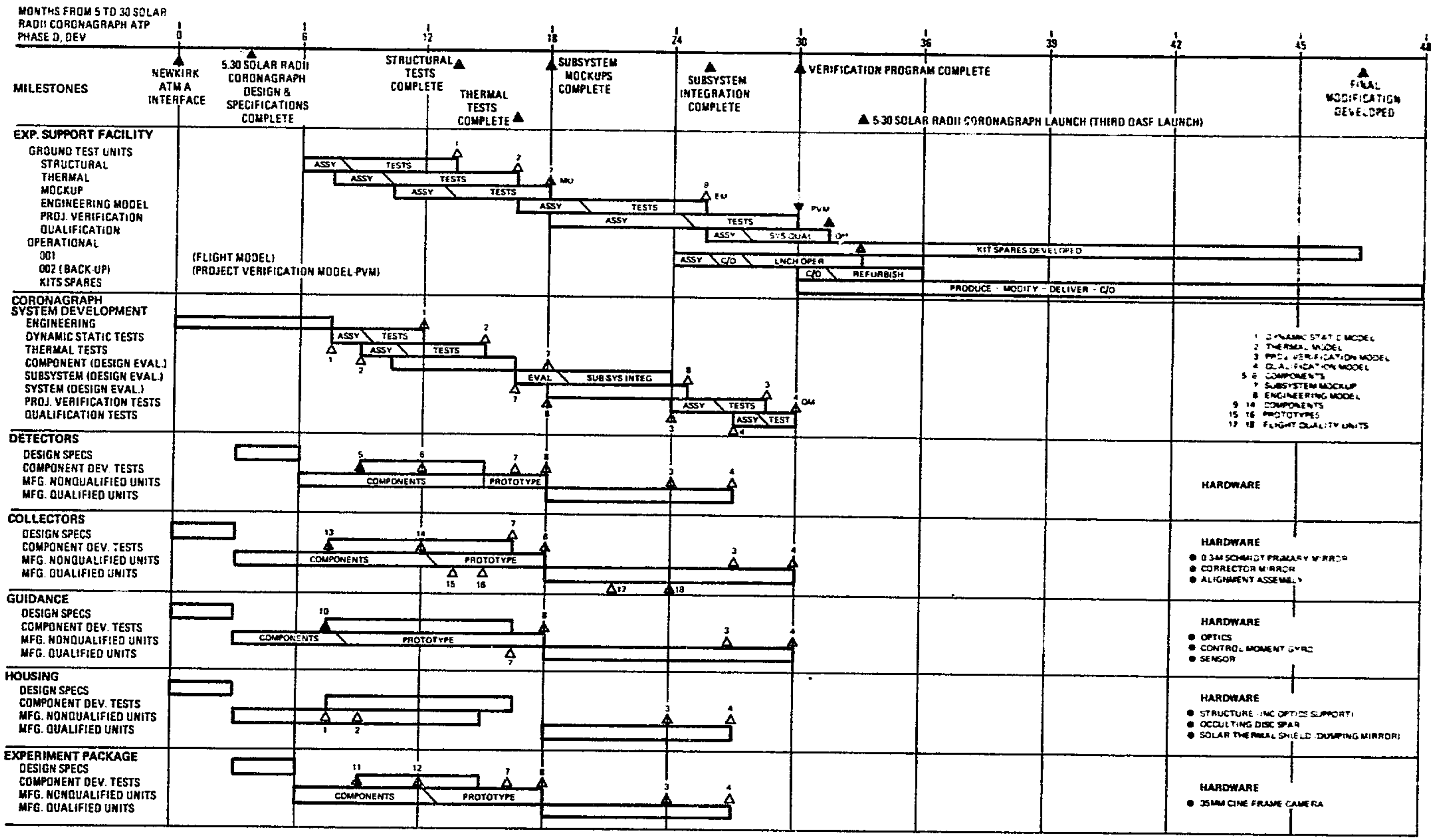
6.5.2 General Characteristics

The X-ray telescope is a large grazing-incidence instrument of the "inside-inside" Wolther Type I category, in which both elements are concave. It has an aperture that is nominally 0.5-m and an image plane about 5-m from the objective. When deployed, the telescope has an overall length of 7.8-m.

The X-ray telescope is built around an optical telescope which serves the func on of guidance and, in addition, is an optical lever about which to stabilize the instrument package at the focus of the X-ray telescope. The X-ray insturmentation is installed on a turntable that can introduce any of the instrumentation devices, one at a time, to the telescope focus. Three instrumentation devices are included; a proportional counter detector, a spectrometer, and an imaging system. Space remains for the installations of additional instrumentation.

The charged ion collectors (electrostatic shields) are for increasing the life of grazing-incidence reflective surfaces, and dectors, used in the X-ray region. Because of the extremely short wavelengths dealt with in this region (1 to 40 Å), the surface smoothness must be held to extremely small RMS variations, on the order of 1 to 2 Å. Pitting, due to the impingement of high-energy particles, that could be tolerated where longer wavelength radiation

(for example, XUV or longer) is involved would degrade the effectiveness of the grazing-incidence reflective surfaces and shorten their useful lifetime. The electrostatic shields are suggested, therefore, as a possible means of reducing the number of high-energy-particle impingements on the grazing-incidence reflective surfaces. This reduction would be accomplished by deflecting charged high-energy particles by the imposition of an electrostatic field.



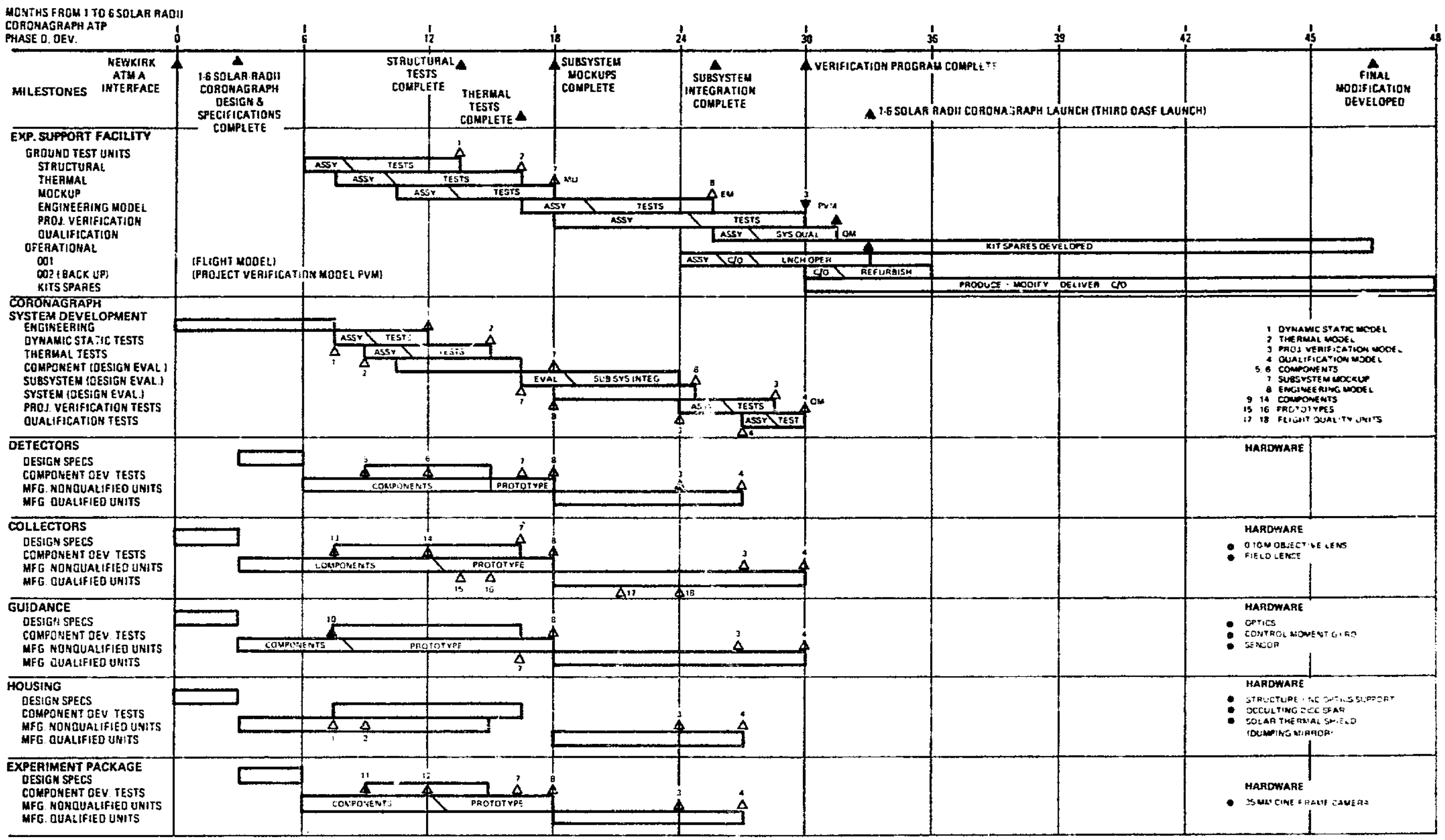
Development Schedule, 5-to-30 Solar Radii Coronagraph Normal-Incidence Telescope

Table 6-29

PRIMARY INSTRUMENT EQUIPMENT LIST--DEVELOPMENT PHASE D
5- to 30-Solar Radii Coronagraph Normal-Incidence Telescope

Functional System (Major Element)	Subsystem	Assemblies	Quantity		
			Bread-board	Proto-type	Flight Quality
5- to 30-solar-radii coronagraph	Detectors	---	---	---	---
	Collecting optics	0. 04-m objective lens	1	2	1
		Field lens	1	2	1
	Fine guidance	Optics			
		Sensor	1	2	2
	Housing	Structure (including optics support)	---	1	2
		Solar thermal shield (dumping mirror)	---	1	2
	Experiment sensors	35-mm cine frame camera	1	1	1
	Major hardware articles	Mockup	1	---	---
		Engineering model	---	1	---
		Project verification model	---	60%*	40%*
		Qualification model	---	---	1

*Obtained from subsystem development quantities.



Development Schedule, 1- to 6-Solar Radii Coronagraph Normal-Incidence Telescope.

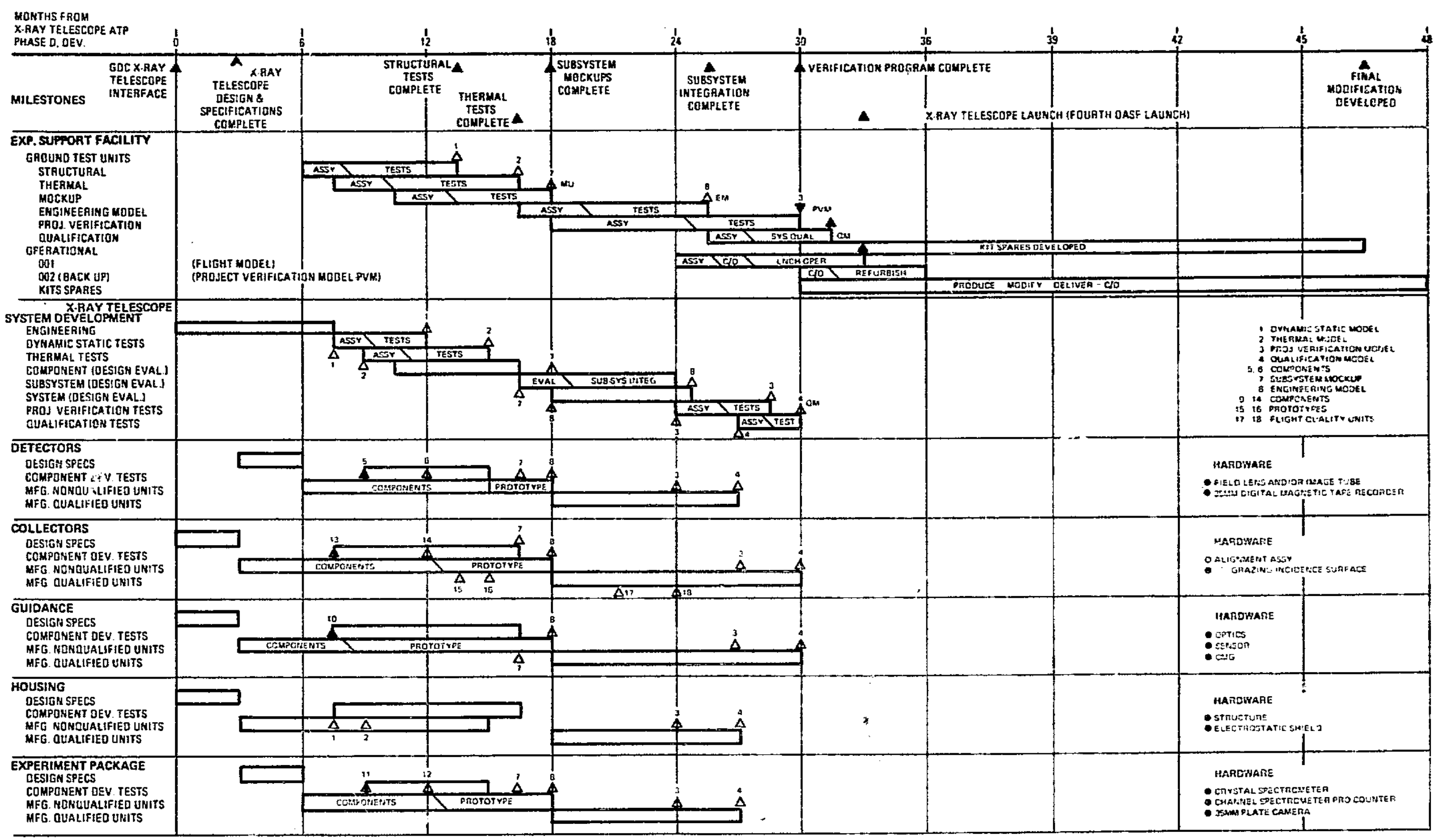
Table 3-63

TASK COST ESTIMATE--PHASE D
1- to 6-Solar Radii Coronagraph Normal-Incidence Telescope, Solar
(OASF Instrument No. 36)

Development total	1,285		
Engineering		95	
Detectors		*	
Collecting optics		12	
0.025-m objective lens			*
Field lens			*
Fine guidance		400	
Optics			*
Control moment gyros			*
Sensor			*
Housing		250	
Structure (including optics support)			*
Solar thermal shield (dumping mirror)			*
Experiment sensors		875	
35-mm cine frame camera			875
Major hardware articles		653	
Mockup			*
Engineering model			*
Project verification model			*
Qualification model			*
Operations total	593		
Flight instrument		385	
Back-up flight instrument		154	
Engineering support		54	
Phase D total	1,878**		

*Cost item not derived where overall estimate for instrument is not significantly affected.

**Assumes previous development of ATM Experiment S052 (Reference 2-6).



Development Schedule, 0.5-m X-Ray Grazing-Incidence Telescope, Solar

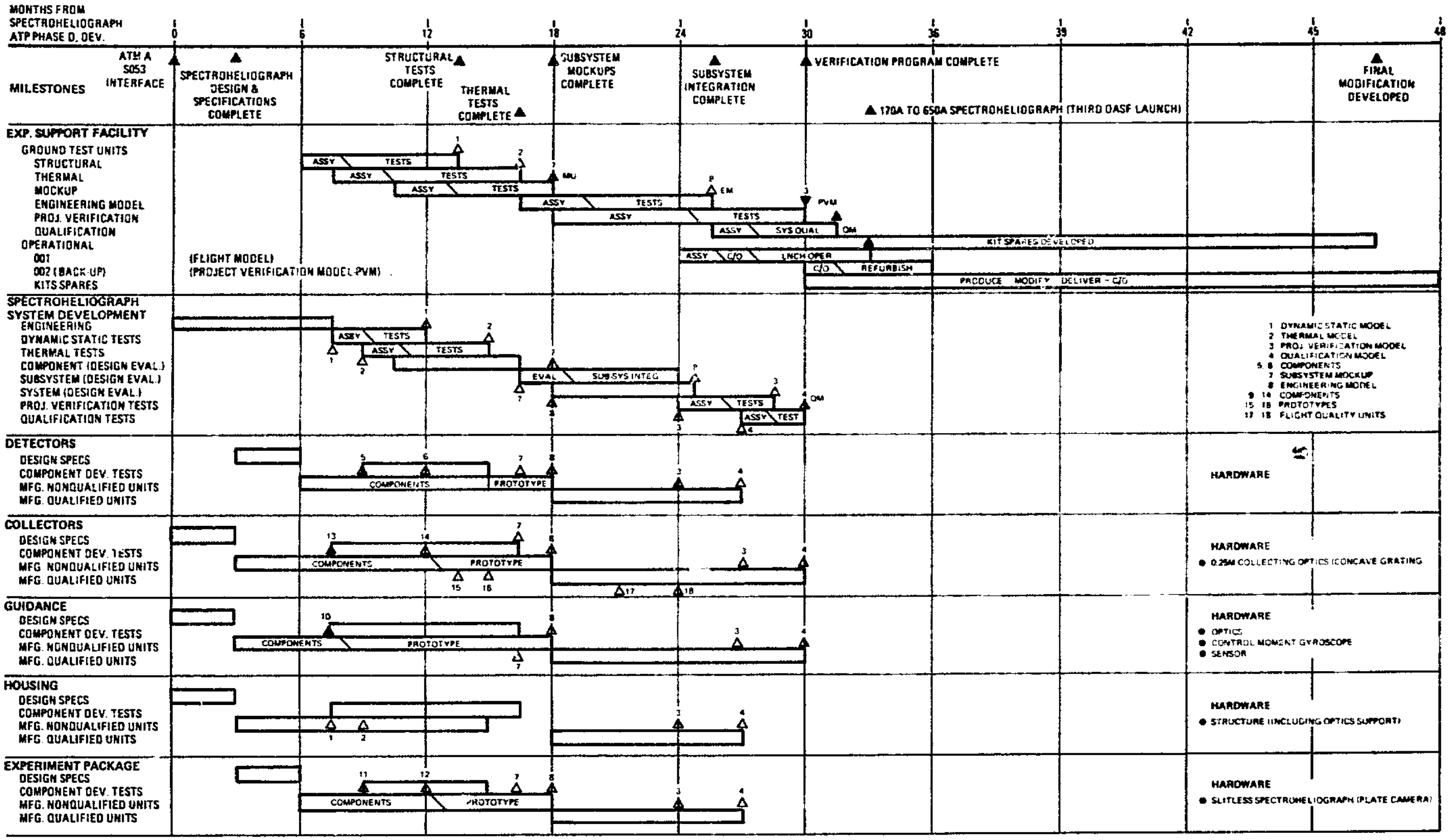
Table 3-170

TASK COST ESTIMATE--PHASE D
1-m X-Ray Grazing-Incidence Stellar Telescope--
OASF Instrument No. 19
($ thousands)

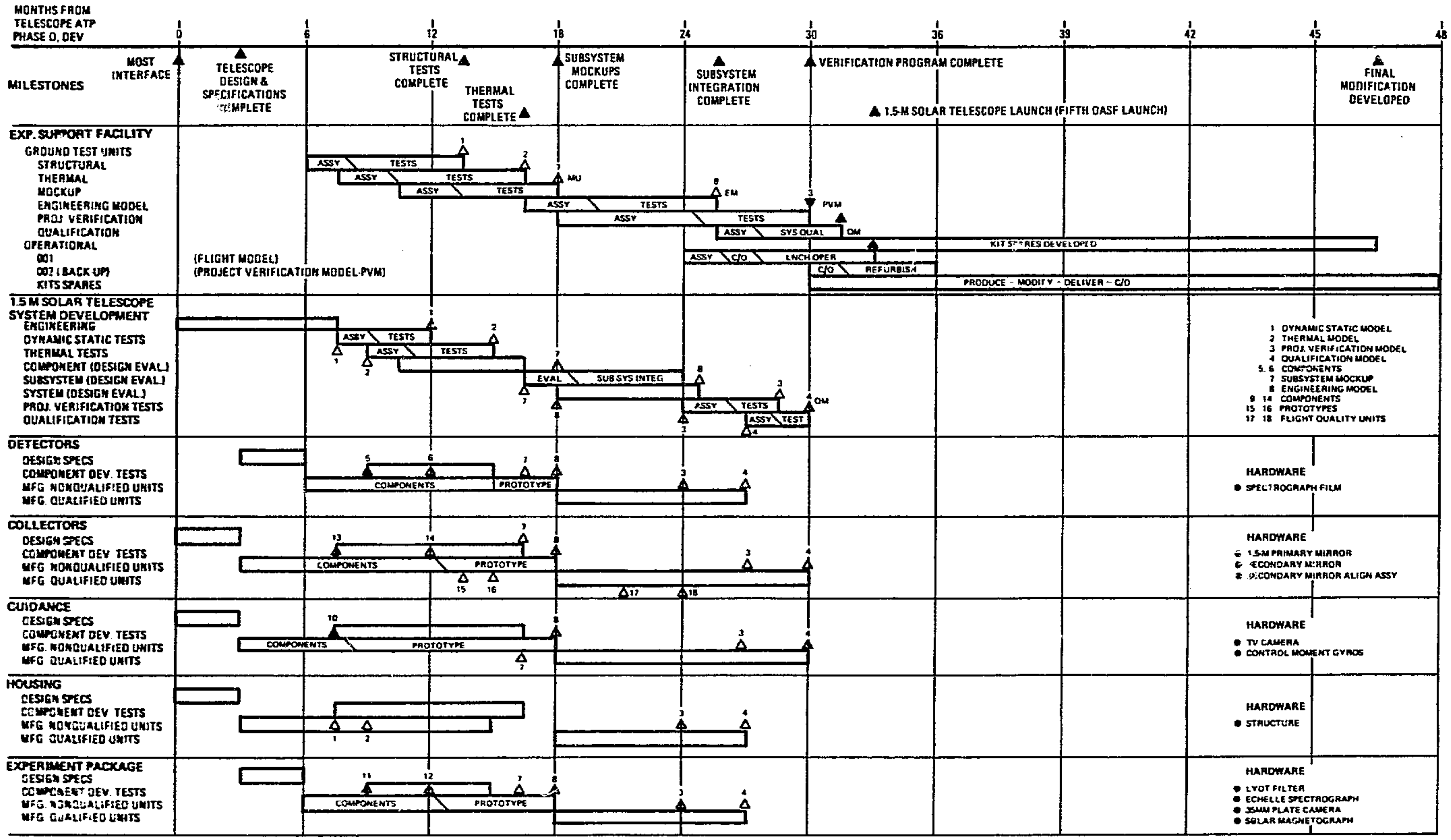
Development total	4, 630		
Engineering		341	
Detectors		*	
Field lens and/or image tube			*
35-m digital magnetic tape recorder			*
Collecting optics		900	
1-m grazing-incidence surface			*
Alignment assy			*
Fine guidance		764	
Optics			*
Sensor			*
Control moment gyro			*
Housing		325	
Structure			250
Electrostatic shield			75
Experiment sensors		1, 100	
Crystal spectrometer			200
35-mm plate camera			600
Channel spectrometer/pro counter			300
Major hardware articles		1, 200	
Mockup			*
Engineering model			*
Project verification model			*
Qualification model			*
Operations total	2, 141		
Flight Instrument		1, 390	
Backup flight instrument		556	
Engineering support		195	
Phase D total	6, 771**		

*Cost item not derived where overall estimate for instrument is not significantly affected.

**Assumes previous development of 0. 25-m imaging X-ray OASF Instrument No. 39 and 0. 225-m spectrographic X-ray OASF Instrument No. 11; same grazing-incidence optics contractor for all three instruments.



Development Schedule, 0.25-Meter XUV Spectroheliograph Normal-Incidence Telescope, Solar.



MONTHS FROM TELESCOPE ATP PHASE D, DEV
0
6
12
18
24
30
36
39
42
45
48
MILESTONES
MOST INTERFACE
TELESCOPE DESIGN & SPECIFICATIONS COMPLETE
STRUCTURAL TESTS COMPLETE
THERMAL TESTS COMPLETE
SUBSYSTEM MOCKUPS COMPLETE
SUBSYSTEM INTEGRATION COMPLETE
VERIFICATION PROGRAM COMPLETE
1.5-M SOLAR TELESCOPE LAUNCH (FIFTH OASF LAUNCH)
FINAL MODIFICATION DEVELOPED
EXP. SUPPORT FACILITY
GROUND TEST UNITS
STRUCTURAL
THERMAL
MOCKUP
ENGINEERING MODEL
PROJ VERIFICATION
QUALIFICATION
OPERATIONAL
001
002 (BACK UP)
KITS SPARES
(FLIGHT MODEL)
(PROJECT VERIFICATION MODEL-PVM)
ASSY
TESTS
MU
EM
PVM
QM
SYS QUAL
C/O
LNCH OPER
REFURBISH
PRODUCE - MODIFY - DELIVER - C/O
1.5 M SOLAR TELESCOPE SYSTEM DEVELOPMENT
ENGINEERING
DYNAMIC STATIC TESTS
THERMAL TESTS
COMPONENT (DESIGN EVAL.)
SUBSYSTEM (DESIGN EVAL.)
SYSTEM (DESIGN EVAL.)
PROJ. VERIFICATION TESTS
QUALIFICATION TESTS
EVAL
SUBSYS INTEG
TEST
1 DYNAMIC STATIC MODEL
2 THERMAL MODEL
3 PROJ. VERIFICATION MODEL
4 QUALIFICATION MODEL
5, 6 COMPONENTS
7 SUBSYSTEM MOCKUP
8 ENGINEERING MODEL
9 14 COMPONENTS
15 16 PROTOTYPES
17 18 FLIGHT QUALITY UNITS
DETECTORS
DESIGN SPECS
COMPONENT DEV. TESTS
MFG. NONQUALIFIED UNITS
MFG. QUALIFIED UNITS
COMPONENTS
PROTOTYPE
HARDWARE
SPECTROGRAPH FILM
COLLECTORS
1.5-M PRIMARY MIRROR
SECONDARY MIRROR
SECONDARY MIRROR ALIGN ASSY
GUIDANCE
TV CAMERA
CONTROL MOMENT GYROS
HOUSING
STRUCTURE
EXPERIMENT PACKAGE
LYOT FILTER
ECHELLE SPECTROGRAPH
35MM PLATE CAMERA
SOLAR MAGNETOGRAPH

FUNCTIONAL PROGRAM ELEMENT IX

ADVANCED HI-ENERGY

1. DISCIPLINE - Astronomy

2. PROGRAM ELEMENT - Advanced High-Energy

3. REQUIREMENT

   Extension of knowledge of location of x- and γ-ray sources and energy spectrum of those sources to much lower energy levels and higher spatial and spectral resolution.

4. JUSTIFICATION

   Provide scientific and engineering background for further studies of x- and γ- ray sources on the NASO Facility. Scientifically, sources requiring detailed study would be isolated. Engineering aspects would be the design of larger instruments and more sensitive detectors, and providing man/machine interfaces for maintenance and updating by man.

5. COMPONENT EXPERIMENTS

   a. Grazing incidence x-ray imaging telescope

   b. Spark Chamber array

   c. Solid state detector array

6. DESCRIPTION

   The advanced high-energy element consists of three basic packages:

   a. Grazing incidence x-ray imaging telescope which requires pointing stability of about $\pm$ 0.2 arc sec. This 1-meter or larger telescope would have at its focus at least two instruments of advanced design, based on results of flight of FPE #I.

(1) Polarimeter for x-rays

(2) Spectrometer for x-rays

b. A low-angular resolution package (a fraction of a degree) consisting of a large area array of digitized spark-chamber of at least 100 sq. ft. to study γ-rays.

c. A medium-angular resolution (a few arc sec.) package consisting of at least several hundred solid-state detectors, for good spatial resolution studies of faint sources of x-rays.

7. SPECIAL CONSIDERATIONS

Unknown at this time.

FUNCTIONAL PROGRAM ELEMENT X

INFRARED AND SUB-MILLIMETER

1. DISCIPLINE - Astronomy

2. PROGRAM ELEMENT - IR and Sub-millimeter

3. REQUIREMENT

   Extension of IR and sub-millimeter (10^{-4}-10^{-2} m) observations to wavelengths and intensities not available from mountains or high-flying aircraft (Aircraft Observatory).

4. JUSTIFICATION

   Provide technological base for instrumentation for detailed studies in this wavelength range on NASO.

   Provide scientific background for detailed studies.

5. COMPONENT EXPERIMENTS

   Large dish mirror of 1 to 2 meter aperature.

6. DESCRIPTION

   The large mirror and the detectors will have to be cyrogenically cooled. The telescope, with a resolution of about 20 arc sec. at 10^{-2} m, will require pointing to about 1 arc sec. or better. This can be provided by the ATM-type mount.

7. SPECIAL CONSIDERATIONS

   Unknown at this time.

EXPERIMENT DATA SHEET

LARGE DISH MIRROR FOR IR AND SUBMILLIMETER ASTRONOMY

1. SPECIFIC OBJECTIVES

Studies of "3^oK" IR background and of specific celestial objects.

2. GENERAL DESCRIPTION

The experiment system will consist of:

a. 1 - 2 meter cyrogenically cooled mirror

b. Cyrogenically cooled instruments at the focus, including possibly.

(1) Broad-band solid state detectors (bolometers)

(2) Solid-state array detectors for field imaging

(3) Grating spectrometer for medium spectral resolution

(4) Michelson-type interferometer for high spectral resolution Fourier-spectroscopy.

Many of these instruments are not state-of-the-art at this time. Technological development of detectors will be provided in connection with the Aircraft Observatory program, and cryogenic systems will be developed for the x-ray polarimeters, described in FPE #I, and other space systems.

3. OPERATIONAL CONSTRAINTS

There are no special constraints: low inclinations and low earth orbit are satisfactory. The ATM-mount will provide the necessary pointing stability.

4. MODE OF OPERATION

Automatic, continuous operation. With the ATM mount, the instruments may operate attached to the space station.

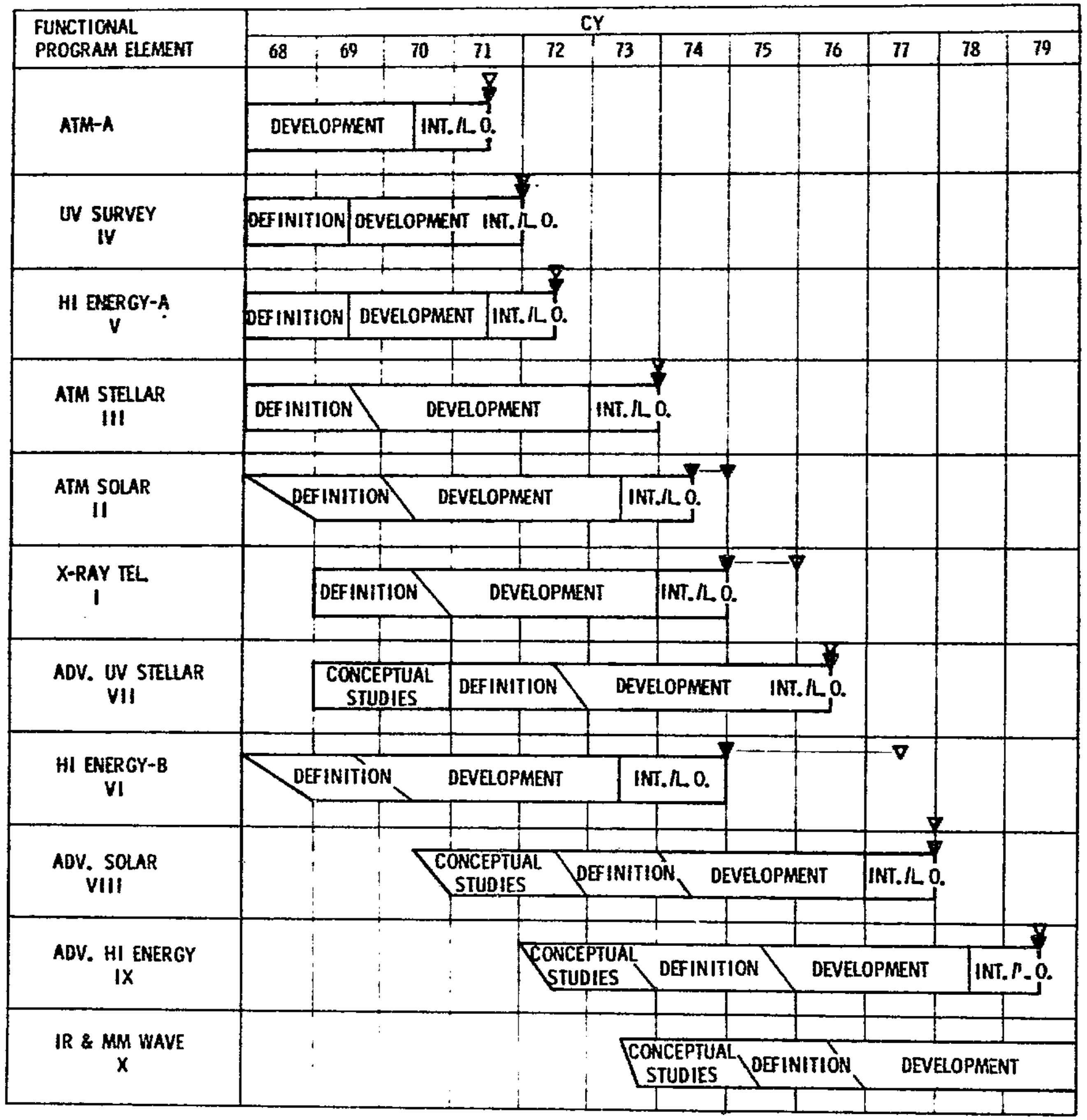
5. CREW SUPPORT

Man will maintain and update the equipment, and will provide replacement cyrogenics when needed.

6. SPACECRAFT SUPPORT

Unknown

EVOLUTIONARY PLAN FOR ASTRONOMY



KEY:

▼ TECHNOLOGY-LIMITED FLT. DATE

▽ DESIRABLE FLT. DATE

A126

CONTENTS

SUMMARY

SPACE PHYSICS

Objectives

To study the physics of high energy cosmic radiation.

To exploit unique characteristics of space to conduct physics experiments not feasible on Earth.

To understand the processes that control the Earth's space environment.

Program

The experiments program incorporate the following major areas of investigation:

a. High Energy Cosmic Ray Physics

The primary objective is the determination of the detailed properties (spectrum and composition) of the high energy cosmic ray particles from 10^{10} to 10^{15} electron volts (eV). A secondary objective is nuclear interaction physics to use the very high energy particles in space to perform controlled laboratory experiments.

b. Physics and Chemistry Laboratory

A laboratory in space offers unique features not attainable on Earth, such as an effectively gravity-free environment, absence of wall effects, etc., to study the physics of solids and liquids and of various chemical reactions. Results to be obtained in the physics and chemistry laboratory will lead to

new insight into the nature of the solid state and show the way to new processes and techniques.

c. Plasma Physics and Environmental Perturbution

Phenomena of plasma physics, under conditions that can't be produced in a laboratory, and of the Earth's environment, including electric and magnetic fields, aurorae, and wave-particle interaction will be studied. Environmental perturbation studies include search for trigger mechanisms that may affect the Earth's environment (radiation, weather, communication...) and means for control of the environment.

d. Small Assorted Experiments

This is a minor area of small experiments to study dim light phenomena such as airglow and gegenschein and cosmic dust.

Experiments Definition

a. High Energy Cosmic Ray Physics Laboratory

The High Energy Laboratory would fit into a module 22 ft. in diameter and 24 ft. in length and would depend upon the central space station for power and data requirements, cryogenics system support and scientist-astronaut life support systems. The instrumentation requirements are such that for reliability and flexibility of operation, the use of a highly-trained man is essential. The Laboratory would continue in operation for a period of one to two years. After this period major changes

and improvements in the instrumentation of the laboratory would be necessary. Payload weight is estimated at 30,000 lbs.

b. Physics and Chemistry Laboratory

This project consists of an experiment program for a space station laboratory. The experiments would be performed in the laboratory of the space station which is assumed to become operational in 1975/76. Astronaut participation in the experiment program will be required. Resupply of the space station laboratory and addition of new experiments may require a certain payload amount in every supply flight to the space station. The experiment program would continue as long as the space station laboratory is operational. Expansion of the experiment program would go in parallel with the increase of facilities as more modules are added to the space station. In the 1977 to 1980 time period a remote experiment module may be required for experiments sensitive to the space station environment (radiation, vibration). Another possibility could be experiment subsatellites. Since specific experiment investigations for the laboratory have not been defined, experiment descriptions are not included here.

c. Environmental Perturbation and Plasma Physics

Use is made in this program of the capability of the space station with subsatellites. The perturbations and plasma injections (chemicals, particles, electromagnetic energy) would be produced from the space station and observed from there as

well as with subsatellites for observation of the injected beam and its subsequent behavior. Specific experiment investigations are essentially yet undefined, however there has been some earlier definition of experiments which are included here as representative.

d. Small Assorted Experiments

This program utilizes the spacecraft as an observation platform for small experiments, such as the airlock experiments, or perhaps subsatellites. The experiments selected for 1971-72 missions are included here as representative.

FUNCTIONAL PROGRAM ELEMENT I

HIGH ENERGY COSMIC RAY PHYSICS

(SPACE STATION LABORATORY)

1. Description

The primary objective is the determination of the detailed properties (spectrum and composition) of the high energy cosmic ray particles from 10^{10} to 10^{5} electron volts (eV). A secondary objective is nuclear interaction physics to use the very high energy particles in space to perform controlled laboratory experiments.

The High Energy Laboratory would depend upon the central space station for power and data requirements, cryogenics system support and scientific-astronaut life support systems. The instrumentation requirements are such that for reliability and flexibility of operation, the use of a highly trained man is essential. The Laboratory would continue in operation for a period of one to two years. After this period, major changes and improvements in the instrumentation of the laboratory would be necessary. Payload weight is estimated at 30,000 pounds.

2. Evaluation Criteria

The High Energy Laboratory will provide access to energetic cosmic ray particles not observable from earth, except by interpretation of secondary particle showers. Statistics from space instrumentation are generally limited by frequency of occurrence and detector size. Thus, the High Energy Laboratory will provide valuable new information on the composition and energy spectrum of primary cosmic radiation.

Ground-based studies of nuclear interaction physics involves large, expensive accelerators to achieve desired particle energies. By using the natural beam of very high energy cosmic ray particles in space, substantive advances in nuclear interaction physics are possible. Initial objectives of the High Energy Laboratory for studies of the properties of the beam at these energies are essential to proceeding with interaction experiments.

3. Phasing

The earliest time of project initiation will depend on the schedule of the space station program. Present plans assume that the first module of the space station will be brought into orbit in 1975. The High Energy Laboratory module could be attached to the space station in the 1975/76 period. It is estimated that a four year flight hardware development program will be required. Therefore, project initiation should occur during FY 72 if a 1975/76 launch is desired.

The present concept of the High Energy Laboratory is based on existing technology. However, improvement in instrumentation technology would be highly desirable.

The following effort would be required prior to project initiation:

a. SRT program for instrumentation development in connection with a balloon flight program.

b. Detailed design study to determine the final configuration with system engineering input. Both activities should start immediately (FY 70).

The project is based on the existence of a manned space station and the participation of a scientist-astronaut in the operation of the cosmic ray laboratory. If the space station program is delayed or the early design would not permit the operation of the cosmic ray laboratory module, a program alternative would be additional flights in the automated high energy physics payload project. However, atuomated payloads cannot accomplish all objectives of the manned laboratory.

4. <u>Schedule and Costs</u>

Time sequence of major events (for 1975-76 launch) are as follows:

Instrumentation development program	1969-1972
Design study	1969-1971
Project initiation FY 72	1971
Flight	1976

Estimates of development and fabrication costs for the laboratory are not available. However, the complexity is compatible to the ATM.

The instrumentation definition program will require a support level of about $3M per year. Definition studies for the Laboratory are provided for in planning activities for the Earth Orbital Space Station.

5. <u>Manpower</u>

Manpower requirements are not available. The technological skills for accomplishing this project are available at either MSC or MSFC.

6. <u>State of Development</u>

Conceptual design studies were initiated in FY 1969 under MSC management.

EXPERIMENT DATA SHEET

HIGH ENERGY COSMIC RAYS

1. DISCIPLINE - Space Physics - High Energy Cosmic Rays.

2. PROGRAM ELEMENT - High Energy Cosmic Ray Experiments.
   Total Energy Spectrometer.

3. REQUIREMENT

   a. Extend low energy cosmic ray measurements, made on scientific satellites over the last few years, into the energy range 10^{10} to 10^{15}eV.

   b. Provide the technological base for the design of a more advanced cosmic ray laboratory capable of not only further extending the cosmic ray measurements but of also utilizing the cosmic rays as a source of ultra high energy particles for doing nuclear and interaction physics.

   c. Study the capability of man to keep a cosmic ray facility operating in orbit for long periods of time.

   d. The very heavy payloads and the long lifetimes necessitated by the low fluxes make the space station the only available means of accomplishing these objectives.

4. JUSTIFICATION

   a. In terms of cosmic ray measurements, one must clearly go to higher energies, because in spite of the extensive measurements at lower energies, questions about the origin, acceleration and

propagation of this corpuscular radiation remain unanswered. Many of the outstanding questions can only be answered by measurements at higher energies.

b. Cosmic rays provide us with a direct sample of matter from their sources, the only material sample we shall have available from outside the solar system for a long time to come. The information which can come from the cosmic radiation is of great current interest. It provides information which is important in relating cosmic rays to optical, gamma and X-ray astronomy.

c. The cosmic ray experiment in itself will be a first step in the development of space facilities for the studies of cosmic rays and the use of the cosmic rays in nuclear physics. In addition it can test the capability of man to keep a more advanced cosmic ray space laboratory actively functioning over long periods of time. Man performs one additional important role. He can provide on the spot reorientation or reconfiguration of the experimental setup. This would be particularly useful in the development of a cosmic ray space laboratory.

5. <u>COMPONENT EXPERIMENTS</u> - A cosmic ray telescope for identifying the charge and direction of a particle and an ionization calorimeter for determining the particle energy.

6. <u>DESCRIPTION</u> - (See experiment data sheet)

7.) <u>SPECIAL CONSIDERATIONS</u>

a.) Any orbit is acceptable which allows a satellite lifetime of up to a year.

b.) The experiment should sweep over a large portion of sky during its lifetime.

c.) As little material as possible should be placed in a 45^{o} cone above the instrument.

d.) The instrument will weigh several tons and will be a highly concentrated mass.

EXPERIMENT DATA SHEET

5.8 COSMIC RAY PHYSICS LABORATORY

5.8.1 Goals and Objectives

A unique feature of the cosmic radiation present above the atmosphere is the very high energies that exist. The intensity of the high-energy cosmic-ray particles is very low, and decreases with increasing energy. This necessitates large instrumentation in order to gather statistically significant numbers of these particles, and very heavy and complex instrumentation to be able to determine their characteristics.

Since these high-energy cosmic rays are direct carriers of information about the nature of their origin and subsequent lifetime in the Universe, the primary objective of this program is astrophysical - to determine the detailed properties of the high-energy cosmic-ray particles from 10^{10} to 10^{15} electron volts (eV). Furthermore, since artificially-accelerated beams of particles provide the probe in investigations into the nature of the fundamental properties of the nucleus and individual particles, a secondary objective is nuclear interaction physics - to use the very high energy particles in space to perform controlled laboratory experiments.

Over the past several years, the NASA scientific program has been highly successful in determining the properties of the cosmic radiation below about 10^{10} eV through the use of small satellites, sounding rockets, and high-altitude balloons. The energy region above 10^{10} eV has not been directly accessible to observation. From the astrophysical point of view, the energy region the cosmic ray laboratory would cover is very important, and has not been well explored. Ground-based accelerators have reached an energy of 7×10^{10} eV (Russia), with the U.S. National Accelerator Laboratory's proposed accelerator to attain 2×10^{11} eV in the mid-70's. With 200 GeV Storage Rings on the NAL accelerator, center-of-mass energies will be achieved that are equivalent to 2×10^{13} eV cosmic rays, at flux levels projected to be about 1000 times higher. Therefore, the main advantage of this facility for interaction physics experiments would be the availability of high-energy heavy cosmic ray nuclei and a very reduced, but possibly useful, flux at energies 10 to 100 times greater than those available on the ground.

The instrumentation requirements for these experiments are such that for reliability and flexibility of operation, the use of a highly-trained man is essential.

5.8.2 Physical Description

The laboratory would fit into a module which could be coupled between other modules in a space station or could be at the end of a series of other modules.

The configuration is illustrated by the attached artist's sketches. A functional description of the various laboratory rooms follows:

Lower Level

Ionization Spectrograph

The central room on the lower level contains the ionization spectrograph (IS), which is the main instrument in the laboratory and comprises about 1/2 its total weight. This instrument provides the energy measurement for all experiments carried out in Experiment Bays 1-4.

Ionization Spectrograph Control Room

All electronics systems providing power to the IS and measuring events occurring in the IS are in this room. Triggering, gating, and routine pulses from Experiment Control Rooms (ECR) 1-4 are provided to the electronics, pulse trains for each event flow to the appropriate ECR after analysis has been completed.

Experiment Bay 1

This experiment bay (EB) contains the detector systems required for interaction physics experiments. (Described later)

Cryogenics Laboratory

Cryogenic storage, control, and possible refrigeration systems are located here. Cryogenic supply could depend upon 60-90 day resupply missions or an on-board refrigerator system, which would require an estimated 2 KW of additional power. An emulsion storage cabinet is provided in the strong-magnetic field volume for radiation protection.

Emulsion Laboratory

This facility would provide emulsion preparation and processing before return to earth.

Experiment Bays 2 and 3

These experiment areas are identical, with the option of using various detector configurations. (Described later)

Experiment Bay 4

This EB is oriented at 45^{o} from EB #2, towards the laboratory module axis. The difference is only that the incident particles must penetrate large amounts of material from some directions, no thin entrance window is provided.

Upper Level

Experiment Control Rooms 1-4

Associated with each EB is a control room which contains all control of the electronics systems required by its associated detectors. Performance of the experiment can be monitored and trouble-shooting performed from here. Remote utilization of the computer for data formating, displaying, and analyses is available.

Data Center

Data output from each ECR is funneled into here for formating, data compression, and preprocessing before transmission to the Telemetry and Data Link Control Room.

Telemetry and Data Link Control Room

Data from the bit chain arriving from the Data Center can be selectively transmitted to the Space Station Telemetry Center or directly to the ground.

Office and Library

A microfilm library on the laboratory instrumentation and relevant physics and astrophysics is available here.

Storage Room

Additional storage over that provided in the ECR's is provided for spare modular electronics systems. Detector components can also be stored here.

5.8.3 Weight, Mass, and Envelope Data

The laboratory module is 22 ft. in diameter and 24 ft. long and will weigh about 30,000 pounds.

5.8.4 Experiment Program

There are four Experiment Bays in which to carry out experiments.

5.8.4.1 Experiment Bay 1

5.8.4.1.1 Scientific Objective

To measure the primary cosmic ray energy and charge spectra up to 10^{14} eV, including the sign of the particle's charge. To carry out measurements of inelastic cross-section and multiplicity distributions in p-p interactions.

5.8.4.1.2 Description

The cryogenic superconducting magnet is the central element in this experiment. The central IS is used for energy determination. Scintillator and Cerenkov counter and spark chambers are used to define the beam, provide electronics triggers to the IS and high voltage systems, and determine the direction and charge of the incident particle. Emulsion plates may be used for ultra-high resolution rigidity determination. A cryogenic liquid Hydrogen target is used in the interaction experiments. EVA is required to remove the outer module wall panel and provide the necessary thin entrance window.

5.8.4.1.3 Observation/Measurement Program

After initial setup, the experiment will operate in an automatic mode for sustained periods of time. It should be operated continuously to collect as many of the higher energy particles as possible.

5.8.4.1.4 Support Requirements

If a closed-loop refrigerator system for the cryogenics is not used, resupply missions between 60-90 days will be required for liquid cryo.

The return of about 50-100 pounds of processed emulsions to earth each 60 days is required.

5.8.4.1.5 Suggested Role of Man

Removal of mechanical support structures for launch is required. The cryogenic systems will be activated and the magnet charged. After set-up and check-out of all systems, the experiment can function for days without the intervention of man except for routine monitoring. The emulsions, when used, will be changed and processed each 2-4 weeks.

5.8.4.2 Experiment Bay 2

5.8.4.2.1 Scientific Objective

To measure the charge and energy spectra of primary cosmic rays.

5.8.4.2.2 Description

The IS is used for energy determination of the particles. The detector system consists of combinations of scintillator counters, spark chambers, proportional counters, and solid or gas Cerenkov counters. The entering particles are analyzed for direction and charge; triggers are provided to the IS for energy measurement. EVA is required to remove the module wall panel to allow the space vacuum into the bay to a thin window entrance on the detector housing. This panel may be inserted for repressurization to allow maintenance in a shirt-sleeve environment.

5.8.4.2.3 Observation/Measurement Program

After initial setup, the experiment will operate in an automatic mode for several days without service.

5.8.4.2.4 Support Requirements

Crew Support

Routine daily monitoring: 15 min.

Orientation

This EB should point away from the earth at all times.

5.8.4.2.5 Suggested Role of Man

Routine monitoring of experiment.

5.8.4.3 Experiment Bay 3

Same as EB #2 with possible different detector configuration.

5.8.4.4 Experiment Bay 4

Same as EB #2 except no thin entrance window, less space for detectors.

5.8.5 Performance Requirement and Subsystems

Crew Support

Deployment time: 15 man-days

Operating time: 8 hours/week

Digital Data:

10 kilobits/second maximum. With the on-board computer, data compression and pre-analyses should decrease the requirement to 2 kilobits average.

Power:

All systems will operate on 1 kilowatt of power, with the exception of a cryogenic refrigerator which would require about 2 kilowatts additionally, if used.

Pointing:

Experiment Bay 2 should point away from the earth at all times. It is desired to know the pointing direction within $\pm 5^{\circ}$ at all times.

Data Return:

Experiment 1 will require 50-100 lbs. of emulsions returned to earth each 60 days.

Orbit Altitude and Inclination:

The altitude and inclination are not critical, although a low-inclination orbit is preferrable to a high one.

5.8.6 Recommended Mode of Operation

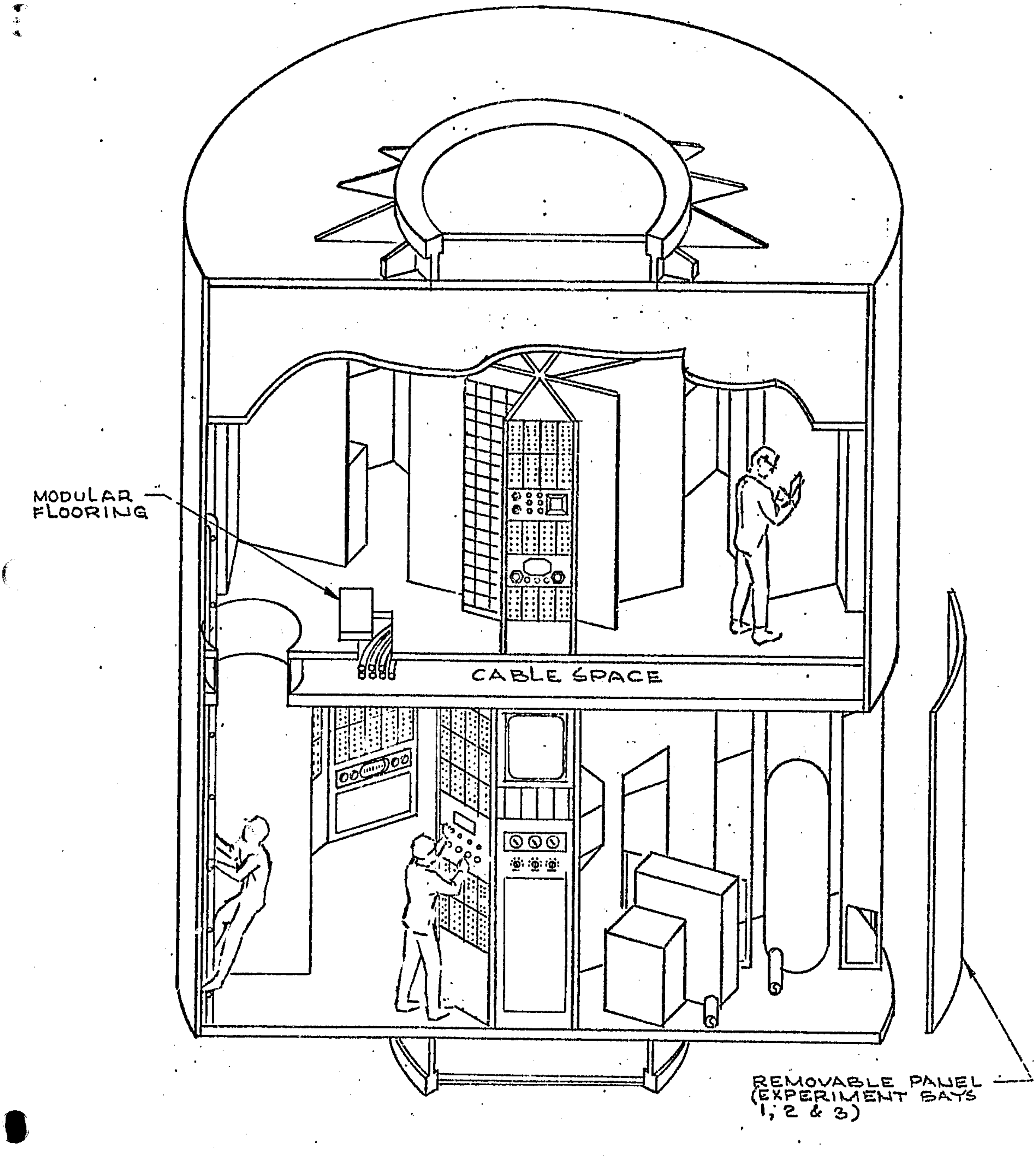
The laboratory experiments all function independently except for the IS which is used by all 4 EB's and the Computer and Data Center. All experiments can be operated in the automatic mode for periods of several days unattended by man.

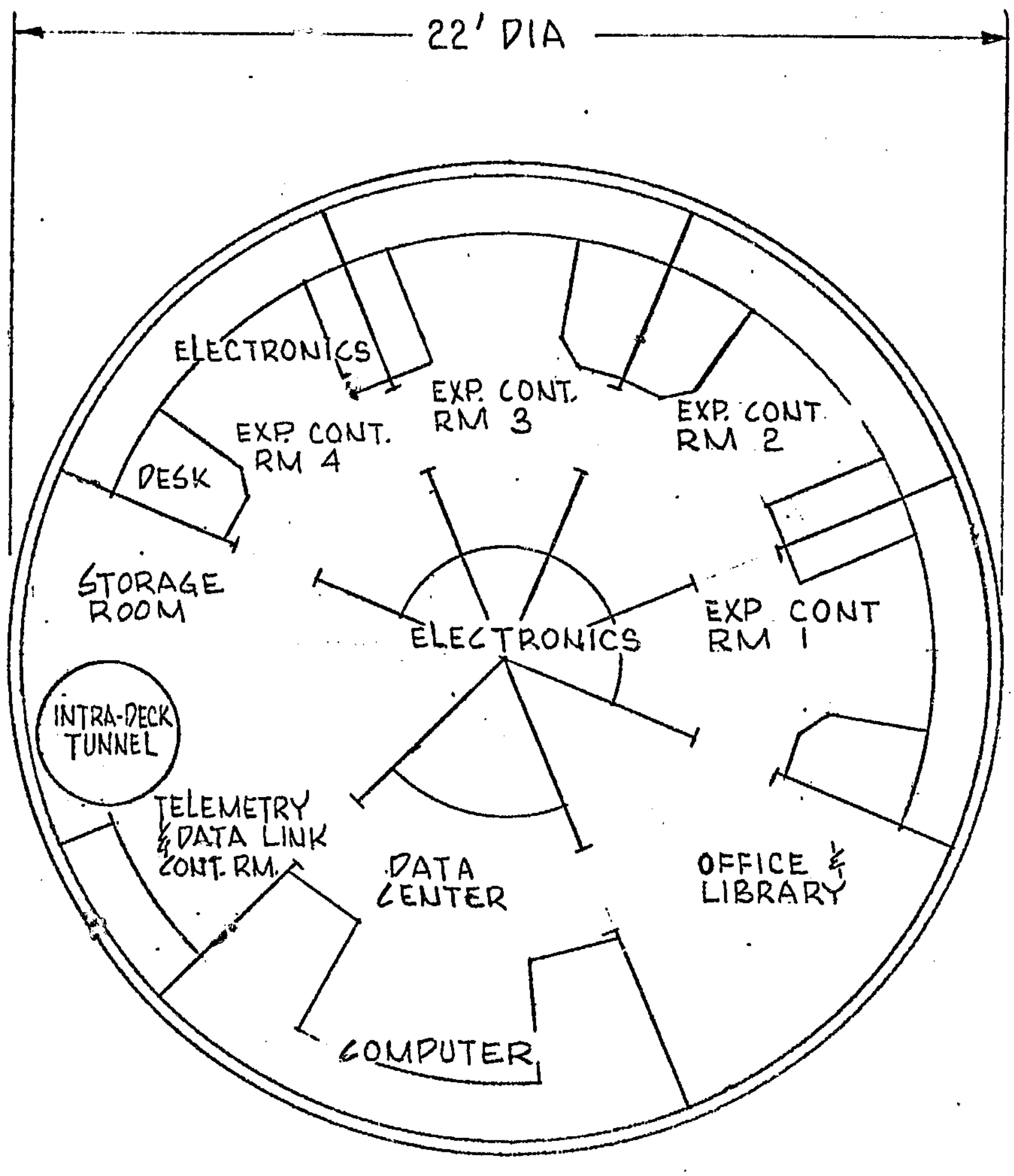
5.8.7 Definition of Station Interface

5.8.8 Role of Man

The man primarily responsible for the operation of the laboratory should be a physicist and thoroughly familiar with all instrumentation and their operating procedure. A less highly trained man will be useful during deployment and for routine monitoring of the experiments.

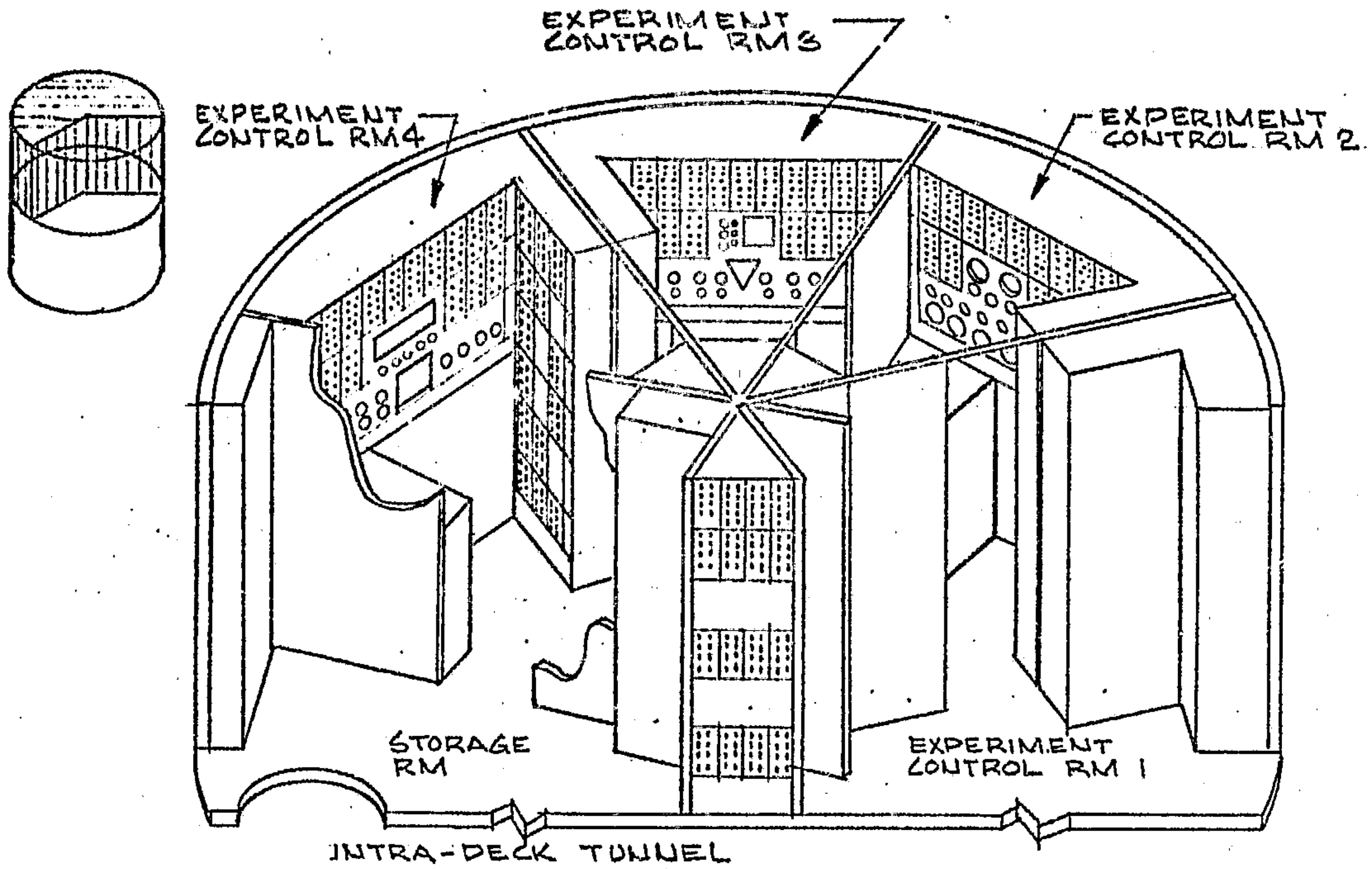
After deployment and check-out has been completed, the primary function of the man will be to monitor the performance of the experiments and to trouble-shoot and carry out maintenance when required.

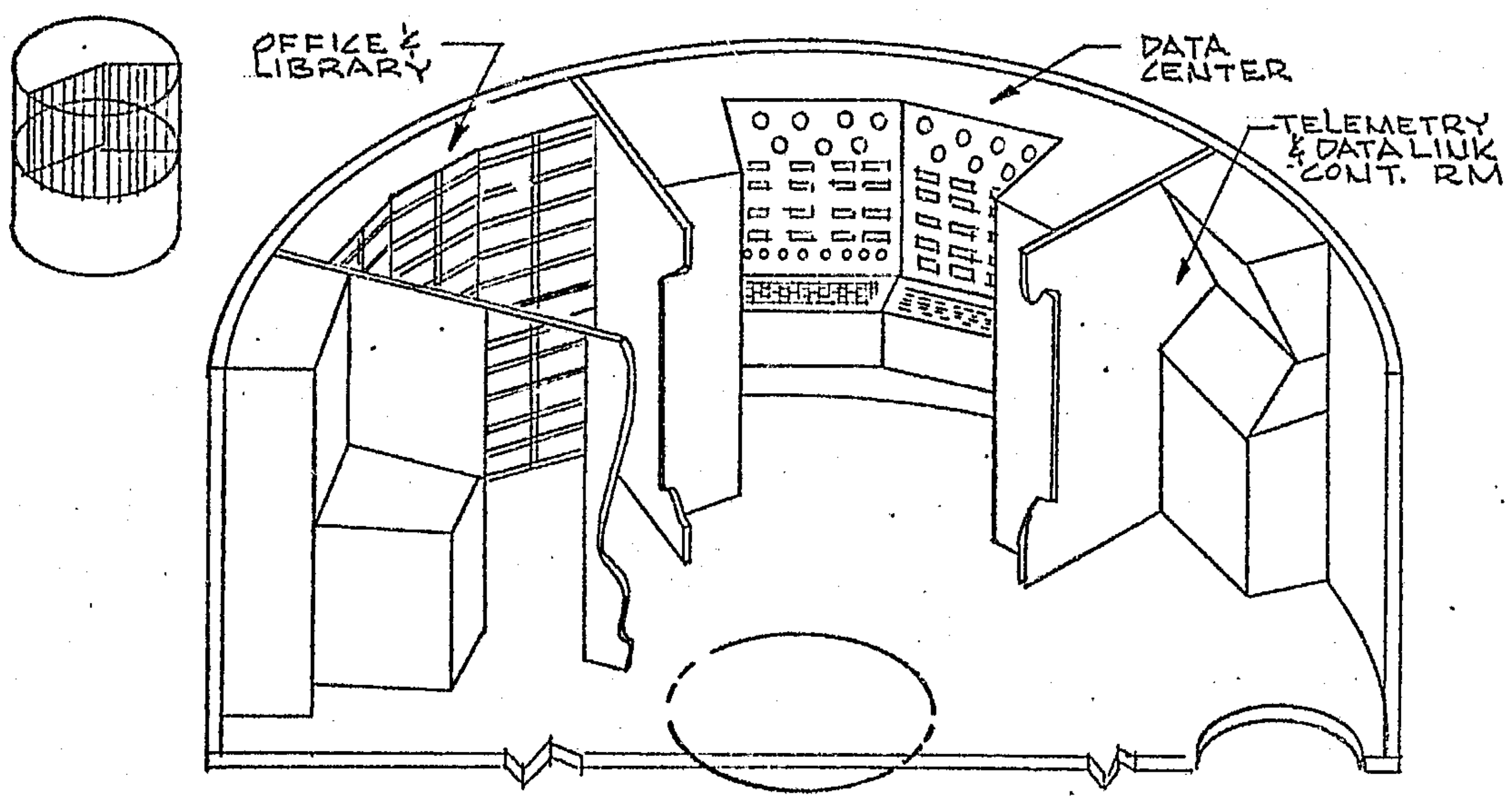

MODULAR FLOORING
CABLE SPACE
REMOVABLE PANEL (EXPERIMENT BAYS 1, 2 & 3)



UPPER LEVEL

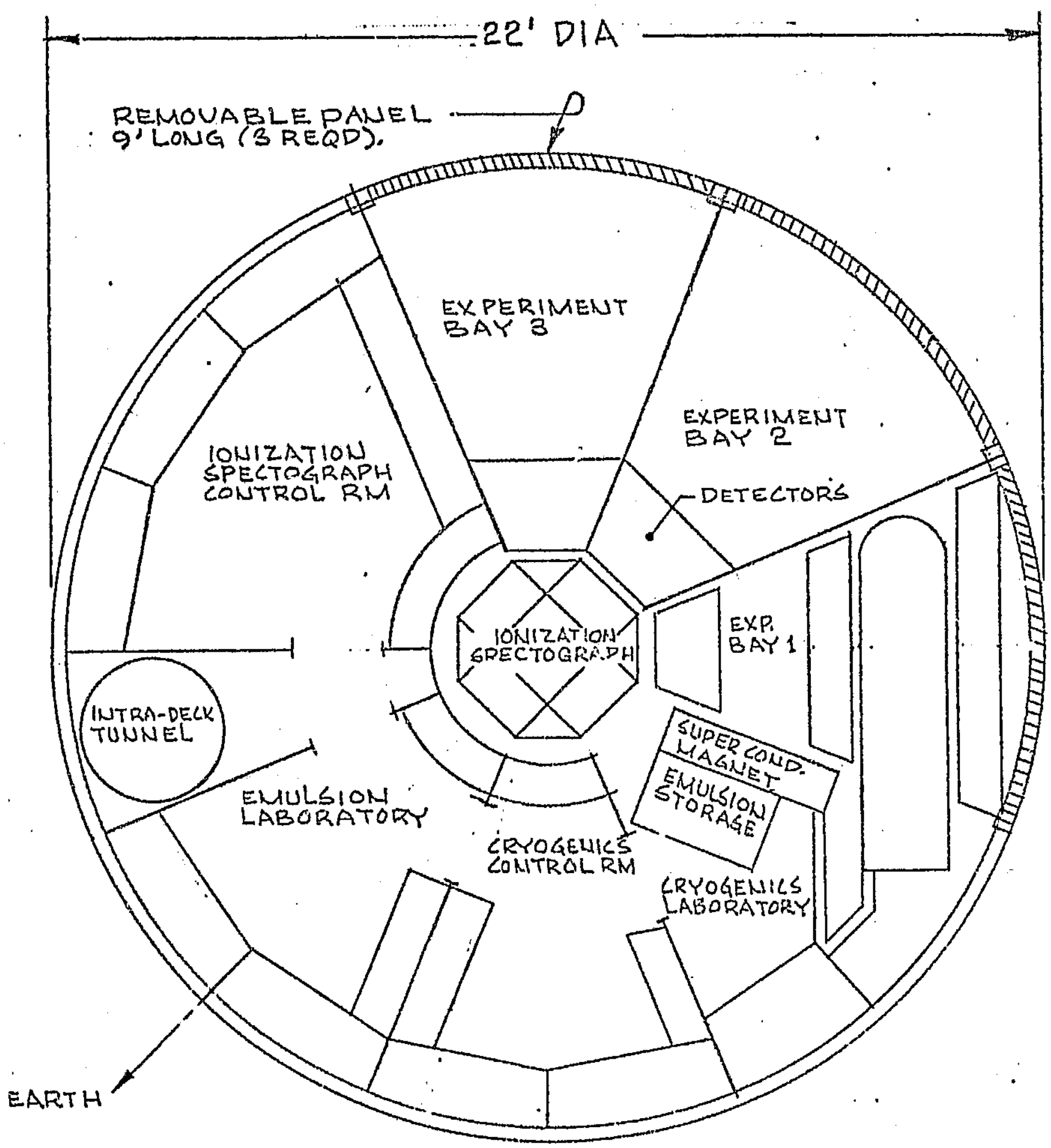
SCALE 1/4" = 1'-0"





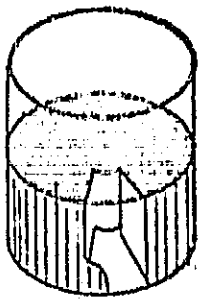
UPPER LEVEL CROSS SECTIONS

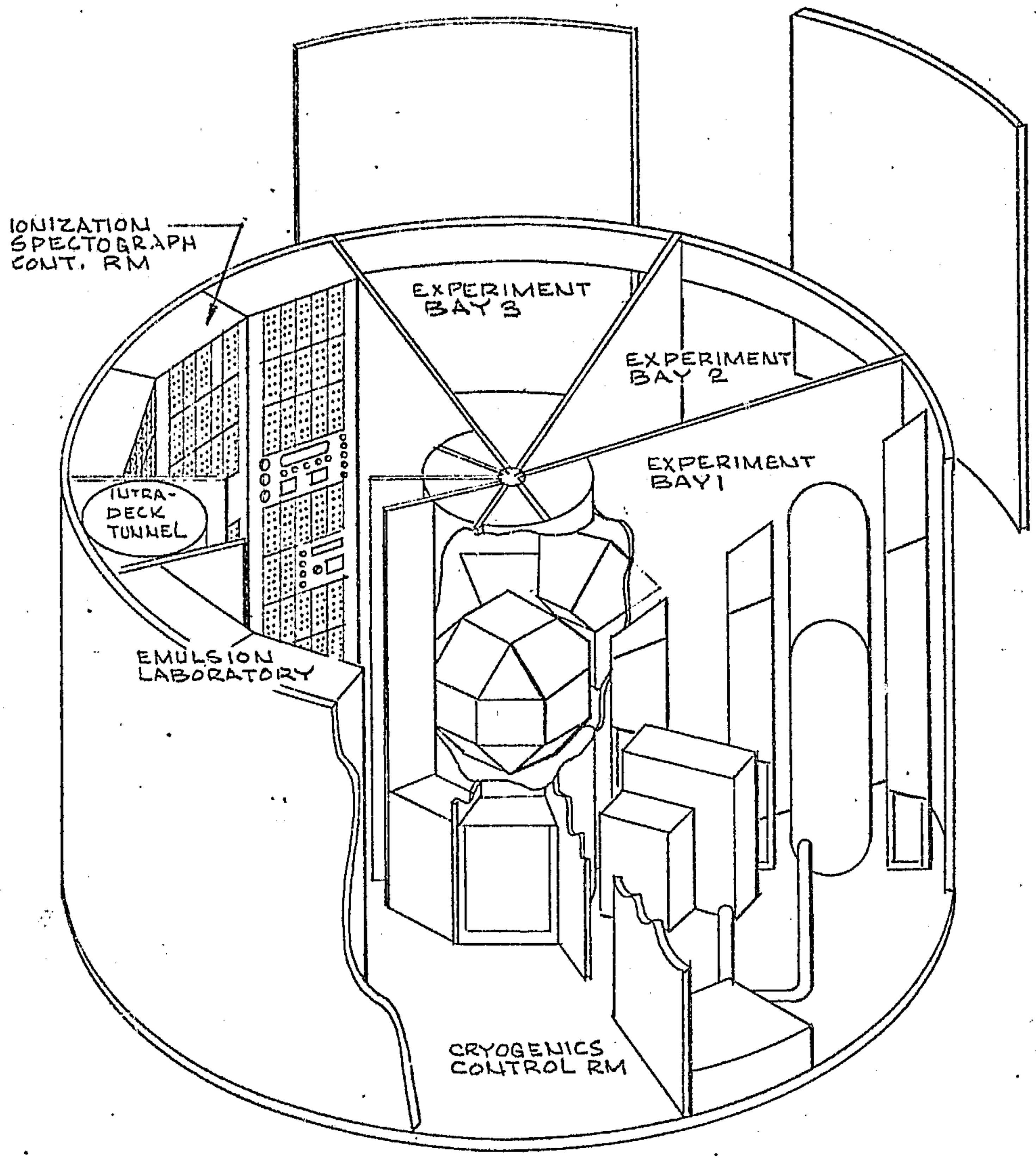
SCALE 1/4" = 1'-0"



LOWER LEVEL

SCALE 1/4' = 1'-0"





LOWER LEVEL CUTAWAY

SCALE 1/4" = 1'-0"

EXPERIMENT DATA SHEET

COSMIC RAYS

1. DISCIPLINE - Space Physics - Cosmic Rays

2. PROGRAM ELEMENT - Cosmic Ray Emulsion - Plastic Detector

3. REQUIREMENT

   a) To extend our knowledge of the composition of primary cosmic ray nuclei above the iron group to and above the trans-uranic group.

   b) To extend our capability to make these measurements beyond that with high-altitude balloon-borne detectors. This requires the improvement of the detection technique, the utilization of man in orbit, and the return of the detector for data analysis.

4. JUSTIFICATION

   a) The presence of primary cosmic ray nuclei with masses in the uranium region and possibly heavier is of great importance in astrophysical studies. A measure of the lifetime of these cosmic rays can be made directly and independently of the interstellar matter through which they have passed. This is the only known way of making this measurement and when considered with the observations of other cosmic rays such as light nuclei and electrons along with the non-thermal radio measurements is important in understanding the nature of cosmic ray sources and the structure of our galaxy.

   b) The extremely low flux of these nuclei indicated by the meager measurements made to date implies that very long exposure times of

large area detectors will be required in order to gain quantitative information. Present balloon experiments are limited in capability for two reasons. The time which a detector can be maintained at a useful altitude is short, of the order of a day, whereas 100 days are desirable. Also, these very heavy nuclei have small nucleas interaction lengths in air and the atmosphere remaining above balloons splatter most of the incoming nuclei before they reach the detector.

c) The radiation problem and resultant darkening of photographic emulsion is serious in this experiment and in many other experiments using film. The inclination and altitude of the orbit are critical because of the S. A. anomaly and unless these are below certain limits, possibly 28.5^{o} and 200 NM, the experiment is not feasible. Enough data should exist on the anomaly to allow a study to determine a reasonable limit on these parameters, however. Also, more development is required in analyzing heavy tracks in emulsion in the presence of lighter tracks to determine limits on the integral flux acceptable from cosmic rays. The most logical way to proceed in developing the ultimate large area detector is to place small detectors in the early workshops in order to evaluate the problems and attempt to solve them. Experience would also be gained on the implementation of the experiment in orbit utilizing the man.

5. <u>COMPONENT EXPERIMENTS</u> - A single emulsion plastic particle detector.

6. DESCRIPTION - The emulsion - plastic detector will be contained in one or more small cases during the launch and recovery phases. The total weight will be between 100 and 200 lbs. The sandwiches of emulsion - plastic will be about 1/4 inch think in areas of from 1 to 4 square feet. These panels could be hinged in a manner which would allow a simple extension to provide a large surface area during deployment or they could be individually placed on a frame provided for this purpose. It is essential that one side of the panels always point away from the spacecraft into space. Before reentry the panels will be returned to the launch configuration and stowed in the recovery spacecraft.

7. SPECIAL CONSIDERATIONS

Orbital Inclination : Less than 28.5°

Orbital Altitude : Less than 200 NM

Pointing and stabilization : Need one side of panels pointing away from earth to ± 10°.

Exposure time: Between 14 and 60 days, depending on orbit and further evaluation of detectors.

Return wt - 100-200#

EXPERIMENT DATA SHEET

HEAVY COSMIC RAY EMULSION - PLASTIC EXPERIMENT

1. SPECIFIC OBJECTIVE - The experiment goal of measuring the charge composition in detail of the primary cosmic ray nuclei heavier than the iron group and particularly in the transmonic region is important in meeting scientific objectives in the cosmic ray astrophysics program.

2. GENERAL DESCRIPTIONS - The detector consists of a sandwich of several layers of emulsion and plastic which records the passage of cosmic ray nuclei. Because of the extremely low flux of these nuclei, it is desired to expose a very large area detector while in orbit. This requires deployment after achieving the desired orbit and a recovery and return of the detector to earth for analyses.

3. OPERATIONAL CONSTRAINTS

a) Stabilization and Pointing - It is required to have the normal direction of one side of the detector surface point away from the earth at all times. It is not required that this direction be stabilized to better than $\pm 10^{\circ}$.

b) Orbital Altitude and Inclination - The allowable exposure time for emulsions will depend critically upon the altitude and inclination of the orbit due to the radiation from the north Atlantic anomaly. It seems unlikely that an orbit whose inclination is above 30° and altitude is above 200 NM would be useful. A careful analysis based on existing data and perhaps a small experiment on early workshop will be required before the trade-offs on exposure time, altitude, and inclination can be finally determined.

4. MODE OF OPERATION - The experiment is passive and requires no continuous monitoring after deployment. It must be outside the spacecraft so no matter exists between the detector and space on the side away from the earth. It should be maintained in this deployed configuration continuously from just after launch until just before reentry.

5. CREW SUPPORT - Very little special training will be required by the crew to unstow and deploy the detector and to recover and stow the unit in preparation for reentry. Two EVA's are required.

6. SPACECRAFT SUPPORT

Weight	:	100
Volume	:	5 - 10 ft^3
Shape	:	Very flexible, could be in several small packages.
Power	:	None
Data Return:		Full Package

7. DEVELOPMENT SCHEDULE AND COST

CY's	PROGRAM	COST
68-72	Detector development through laboratory and balloon work	$1 M
69-72	Design, fabricate, and deliver small detector for early workshop as part of development program for intermediate workshop.	$1 M
72-74	Complete design of final detector for intermediate workshop based on development program, Fabricate and deliver detector unit.	$1 M

FUNCTIONAL PROGRAM ELEMENT II

PHYSICS AND CHEMISTRY LABORATORY

1. Description

This project consists of an experiment program for a space station laboratory. The experiments would be performed in the laboratory of the space station which is assumed to become operational in 1975/76. Astronaut participation in the experiment program will be required. Resupply of the space station laboratory and addition of new experiments may require a certain payload amount in every supply flight to the space station. The experiment program would continue as long as the space station laboratory is operational. Expansion of the experiment program would go in parallel with the increase of facilities as more modules are added to the space station. In the 1977 to 1980 time period a remote experiment module may be required for experiments sensitive to the space station environment (radiation, vibration). Another possibility could be experiment subsatellites.

The first step required to start the project must be an extensive experiment definition program.

2. Evaluation Criteria

The objective is to study the physics of solids and liquids and various chemical reactions in the zero-g environment of space which cannot be duplicated on earth. A number of promising areas for investigation have been identified. The absence of density gradients and convection may yield new phenomena. Investigations about crystal growth and quantum behavior of liquids at low temperature are two promising examples. The type of experiments considered for this project would provide the basic knowledge required for the application oriented effort "Manufacturing in Space."

3. Phasing

The earliest time for project initiation i.e., start of the flight hardware development program would be FY 1973. This must be preceded by an experiment definition and development program involving experts in related areas throughout the scientific community. A well funded experiment definition program should start in FY 1971. Only after completion of the first phase of such a program the overall magnitude of the project could be determined.

Sequence of events:

Experiment definition and development program (Start FY 71)	1970-1972
Experiment selection (for flight hardware development)	1972

Project new start FY 1973	
Flight hardware development, start FY 1973	1972
Begin of experiment transportation to space station	1975/76
Experiment operation, updating and addition	1975-1980
Remote experiment module/subsatellites	1978-1980

This project is based on the availability of a manned space station laboratory. If such a facility in space will not be available or will become operational much later than presently anticipated, the most important and desirable experiments identified in the experiment definition program could be performed in an unmanned, automated payload.

4. Cost Estimate

At the present time only the cost of the experiment definition and development program can be estimated:

FY 71	$1.5 Million
FY 72	$3.0 Million

These estimates do not provide for phase A/B studies for the laboratory facilities. These are included in the Manned Space Station planning activities.

5. Manpower Requirements

The experiment development and definition program would be coordinated and supervised by one or two people at Headquarters. A group of about 10 people at a center (MSFC?) would be sufficient to start these activities.

FUNCTIONAL PROGRAM ELEMENT III

PLASMA PHYSICS EXPERIMENTS

1. Description

It is proposed that plasma physics experiments be considered in connection with a Manned Space Station.

These are discussed below and include the following:

(a) Field Line Geometry Measurements
(b) Ionized Barium Cloud for Electric Field Measurements
(c) Whistler mode Wave-Particle Interactions
(d) Detection of Electromagnetic Field Transients in the Magnetosphere
(e) Electron Beam-Plasma Interactions

(a) Field Line Geometry

Significant work is underway to prove the feasibility of placing an electron gun in space to fire 0.1 second bursts of 1-10 Kev electrons along magnetic field lines with the purpose of having the electrons form an artificial aurora upon impacting the atmosphere. The flash of light so produced serves as indicator of the position of the foot of the field line passing through the electron injection point. Such an experimental device located on a space station will allow mapping of the magnetic field lines of the magnetosphere since the high velocities of the electrons injected will suffer little lateral deflection. The location of conjugate points on magnetic field lines should be detectable with this experimental apparatus to a precision two orders of magnitude better than presently known values.

(b) Electric Field Measurements

A developed experimental technique for observations of electric fields in the magnetosphere uses chemical releases of neutral barium. The ejected barium will be ionized by sunlight and the resulting liminous plasma blob will expand both along the magnetic field line on which it is placed and transverse to it, thereby compressing the magnetic field around it. After an initial transverse expansion phase the magnetic field will diffuse back into the plasma and further diffusion of the particles across the field lines will be a measure of the fluctuating electric fields present in the ambient medium. Also, the net drift of the plasma as a whole is a measure of the static electric

field present since the plasma and the magnetic field line to which it has attached itself are subject to a drift force. Thus, by observing the transverse expansion and drift of the cloud, information about the electric fields in indirectly obtained. It is proposed that the chemical releases by initiated from the space station and that either the space station or a subsatellite, as appropriate, be used for observation of the interactions.

(c) Whistler Mode Wave-Particle Interactions

Much progress has been made in recent years in studying properties of the magnetosphere up to about four earth radii by means of observing VLF signals propagating along magnetic field lines via whistler modes.

Further, if VLF transmitters are located on a space station a wider class of experimental parameters becomes available with a much lower expenditure of transmitter power. In particular the angle between the wave number vector and the magnetic field vector has a much wider latitude for a satellite borne transmitter. Much information on wave-particle interactions would be obtainable in such experiments.

It would be desirable to augment such measurements by placing a satellite electron pitch angle detector in an appropriate position to monitor the effects on this quantity of transmitted signals.

(d) Detection of Electromagnetic Field Transients in the Magnetosphere

It is known that for magnetic shell L-values greater than two there are transient fluctuations both in the electromagnetic fields and the electron population which are associated with geomagnetic disturbances. These disturbances are thought to be ultimately caused by fluctuations in the parameters describing the solar wind, and the times of their occurrences are largely unpredictable. Measurement of the transient electromagnetic fluctuations during such disturbances will help clarify the nature of those events. Such measurements could perhaps be profitable done from a manned space station since only a minimal monitoring effort is required continuously in order to determine the onset of one of these sporadic disturbances. During the disturbances a somewhat larger effort could be expended in making actual measurements.

(e) Electron Beam-Plasma Interactions

The physics of the interactions between a plasma beam and an ambient plasma into which the beam is injected is quite complicated. Although linearized theories (and some quasi-linear theories) exist and are able to predict the onset and/or early development of instability in many cases, it is generally true that little as known about the final states toward which the instabilities drive the system. By injecting an electron beam into the upper ionosphere from an orbiting spacecraft one could observe the initial expansion phase of the beam

to the point where a balance between plasma beam pressure and magnetic pressure is achieved. The subsequent appearance of streaming instabilities result in particle velocity randomization, and the final phase of behavior is one in which the faster particles of the beam move to the front, recreating the conditions for the two-stream instability and the onset of a shock-like structure at the front of the beam.

An electron accelerator capable of producing such a beam could be built by extending presently available paper designs and would weigh perhaps 1000 lbs. including its power supply.

Meaningful observation of the injected beam and its subsequent behavior would need to be done from space, perhaps from a vehicle other than the injecting one. Measurements which would be made include spectroscopic analysis of the optical radiation from the beam which would yield information concerning the temperature, density, and diffusion rate of the beam and radio detection of other beam emissions such as electron cyclotron plasma waves from the main body of the beam and electromagnetic radiation near the front of the beam. These measurements could be made with relatively lightweight equipment either on board a manned space station, or on a second satellite.

2. Evaluation Criteria

The advantages of performing these experiments in space are that a collisionless ambient plasma is readily available and there are no confining walls serving to complicate the behavior.

Measurements could be attempted from the ground, however, the low level of the signals and the intervening ionosphere would render such measurements very difficult.

3. Phasing

It is proposed that these experiments be studied to determine the required instrumentation for ejecting or transmitting perturbing chemicals or radiation from the space station and observational requirements in terms of space station equipment, or subsatellites.

Assuming a space station is available in 1976, this program should be initiated as a development project in 1973.

4. Schedule and Costs

Studies by competent workers in plasma physics should be supported in FY 1971 for the purpose of defining appropriate goals and methods for such experiments. These studies are estimated at 1.5M/yr.

5. Manpower

Manpower requirements for these experiments, assuming they are done serially, are estimated at 20 men per year. Either MSFC or MSC could manage this program.

6. Status

Only preliminary scientific studies have been made. These are included in "Report of Ad Hoc Committee on Environmental Modification Experiments in Space to the National Aeronautics and Space Administration, March 1968."

A 10 Kev electron accelerator for artificial aurorae experiments (Hess, MSC) has been launched on a rocket.

Successful barium releases by sounding rockets and satellites (Heos) have been ovserved and have provided valuable initial data on electric fields in the magnetosphere.

EXTENDED DESCRIPTIVE MATERIAL

1. Discipline - Space Physics - Plasma Physics

2. Component Elements - Six experiments are envisioned in this FPE, representing three subgroups of two experiments each. The first two involve magnetic and/or photographic observation from a manned space station of ionized barium cloud releases in the sunward side of the earth's magnetosphere. In one case the barium release cannister would be ejected from the space station itself and in the second case a separate rocket would deposit the cannister.

   The second subgroup involves the observation of particle beams injected into space from the manned station or from a subsatellite. First, an electron accelerator mounted on a suitable subsatellite could inject an electron beam into the upper ionosphere which could in turn be observed by photographic, spectroscopic, and radio means in order to provide basic plasma physics data concerning beam-plasma interactions. Second, a plasma jet engine mounted on the manned station could be operated and monitered by the above means. The hard vacuum of space would allow this device to serve both as a basic experiment in the flow of magnetoplasmas into vacuum and also as a prototype device for a station keeping thruster.

   The third subgroup includes two ionospheric plasma investigations which were included in earlier versions of this FPE. The first involves radio signal propagation between antennas of variable orientation in order to test warm ionospheric plasma propagation theory. The second experiment involves use of subsatellites to make measurements of the plasma wake of the manned space station itself and also of more symmetrical bodies such as an inflatable sphere subsatellite.

3. Requirements - (a) The barium cloud release from the space station itself would require a geostationary orbit with the station positioned on the daylight side of the earth. Photographic camera operated by a scientist-astronaut would record the behavior of the cloud and a small subsatellite carrying a three-axis flux gate magnetometer would be maneuvered onto the magnetic field line passing through the cloud in order to record transient changes in the magnetic field.

Unfortunately such experiments cannot be carried out on the daylight side of the magnetosphere since such clouds would not be visible from the ground against a lighted sky. A space station in geostationary orbit, however, would be in an excellent position to perform such an experiment completely unassisted on the daylight side. A space station in a lower orbit (say 270 nautical miles) could observe a ground launched cloud on the daylight side.

Experiments (c) and (d):
The physics of the interactions between a plasma beam and an ambient plasma into which the beam is injected is quite complicated, giving rise to many kinds of instabilities, both MHD and microscopic. Although linearized theories (and some quasi-linear theories) exist and are able to predict the onset and/or early development of instability in many cases, it is generally true that little is known about the final states toward which the instabilities drive the system. By injecting an electron beam into the upper ionosphere from a subsatellite of the manned station or a separately orbiting spacecraft, the scientist-astronaut could observe the initial expansion phase of the beam to the point where a balance between plasma beam pressure and magnetic pressure is achieved. The subsequent appearance of streaming instabilities result in particle velocity randomization, and the final phase of behavior is one in which the faster particles of the beam move to the front, recreating the conditions for the two-stream instability and the onset of a shock-like structure at the front of the beam. The advantages of performing such an experiment in space are that a collisionless ambient plasma is readily available and there are no confining walls serving to complicate the behavior. Meaningful observation of the injected beam and its subsequent behavior would need to be done from space, perhaps from a vehicle other than the injecting one, so that such an experiment could be profitably performed with the aid of a manned space station.

In the case of experiment (d) the plasma jet would be injected from the manned station itself which would be at such an altitude (say 270 nautical miles) that the vacuum of space is superior to that of any suitable earth based facility. Because of this fact the behavior of the plasma jet at the nozzle, including the very important phase of detachment of the plasma from the magnetic field of the device, could be observed in detail not approachable on earth. In addition to these basic aspects, the experiment would provide an engineering evaluation of the plasma jet as a prototype of a station keeping thruster for advanced space missions.

(b) A manned station in the nominal 270 nautical mile altitude orbit would observe and record on photographic film a barium cloud release launched by a Scout rocket into the magnetosphere on the daylight side of the earth.

(c) A spectrographic camera, photographic camera, and radio receiver would be mounted on a 270 nautical mile altitude manned station and would be used to moniter an electron beam ejected from an accelerator on board a subsatellite (or alternatively on board a separate satellite) in the upper ionosphere.

(d) A plasma jet engine would be installed on the manned station and operated by a scientist-astronaut. Measurements as in (c) above would be made and in addition Langmuir probes could be mounted on booms and moved about from time to time by the astronaut in order to observe the flow in various regions of the nozzle.

(e) Radio signal impulses of varying frequency would be transmitted between manually located and oriented antennas located on booms on the manned station. The propagation time as a function of frequency and antenna orientation would reveal the dispersive properties of the ionospheric plasma medium between the antennas.

(f) Plasma probes located on a subsatellite maneuvered by the scientist-astronaut would be used to map the plasma wake generated by the manned station as it moves through the ionospheric plasma. Also, one or more inflatable satellites of spherical and/or cylindrical shape would be released by the manned station and the wakes created by these symmetrical bodies would be probed by the maneuverable subsatellite.

4. Justification - Experiments (a) and (b) above:
Obtaining knowledge of the plasma flow patterns is one of the primary goals of magnetospheric physics, and since particle movement in a magnetoplasma is intimately related to the electric fields, it is of paramount importance to be able to measure these fields. An excellent method for doing this is to observe the drift motion and expansion of a visible plasma cloud. The feasibility of depositing photo-ionizable barium clouds in the earth's magnetosphere with subsequent optical observation of the luminous plasma has been demonstrated. Experiments are currently under way to launch such clouds into the twilight or pre-dawn regions of the earth's magnetosphere at altitudes of about 5 earth radii. After the plasma cloud has attached itself to the local magnetic field lines, it is subject to a general lateral drift under the action of any static electric field present and to a radial expansion as the fluctuating electric fields present cause the plasma particles to diffuse outwardly across the magnetic field. Photographic observations of these motions from the ground then provide an excellent means for determining the nature of these electric fields.

Experiments (e) and (f):
Since it is not possible to duplicate the ionospheric plasma in a laboratory, the opportunity afforded by a space laboratory to investigate it in some detail is unique. By means of low-energy particle sensors placed on a small satellite, which can be positioned at will in the near vicinity of the laboratory, measurements of electron and ion density, temperature profile can be obtained with the spacecraft wake experiment; by propagating radio waves at different frequencies through a large (hopefully homogeneous) ionospheric plasma volume between the laboratory and the sub-satellite, the ambient electron and ion temperature, density and composition can be measured.

Both of these measurements will add to our understanding of the ionospheric plasma.

EXPERIMENT DATA SHEET

BARIUM CLOUD CANNISTER EJECTION EXPERIMENT

1. Specific Objective - To observe static and fluctuating electric field patterns in the sunward portion of the earth's magnetosphere in the neighborhood of synchronous orbital altitude (5 earth radii altitude).

2. General Description - As envisioned the experiment would consist of having the manned space station in geostationary orbit eject (along the magnetic field lines) a cannister containing appropriate chemicals for producing a neutral barium cloud. A simple spring or a small reaction jet could be used to propel the cannister. At some distance away the cannister would be ignited and the resulting neutral barium cloud would become photo-ionized. Because of its position on the some magnetic field line the manned station would be in an excellent position to record magnetic field disturbances produced by the sudden appearance of the cloud as well as to photograph the subsequent motion of the cloud. The magnetic field measurements would probably have to be made from a sub-satellite because the space station itself would act as a disturbing influence upon the magnetic field

3. Operational Constraint - (a) Both barium cannister and subsatellite carrying magnetometer must be ejected along some magnetic field line. Subsatellite to telemeter magnetic field data back to space station.

   (b) Photographic cameras to be placed on appropriate mounts to allow for time exposure photographs. This may necessitate an automatic tracking servo mount or at least a pre-programmed motor driven mount.

   (c) Position of space station must be known sufficiently accurately that star charts may be used in conjunction with star images on cloud photographs to determine position and extent of cloud.

4. Mode of Operation - Manned station ejects steerable barium cannister and magnetometer subsatellite along magnetic field line. Subsatellite could also be used in common with unrelated experiments so long as design is "magnetically clean".

5. Crew Support - Scientist - astronaut ejects and remotely steers cannister and subsatellite and moniters magnetic field telemetry. He also operates camera to record photographs of cloud behavior.

6. Spacecraft Support - Subsatellite 3 axis fluxgate magnetometer - 5#
Barium cannister release equipment - 20#
Photographic camera - 6"f.L. f2 with servo driven mount - 35#

7. Development Schedule and Costs -

70-71	Study
71-72	Steerable Barium Cannister
	Magnetometer Package
	Camera and Mount
72-73	Space Station Hardware

EXPERIMENT DATA SHEET

BARIUM CLOUD OBSERVATION EXPERIMENT

1. Specific Objective - To observe static and fluctuating electric fields and plasma flow patterns in selected regions (such as the neutral points on the magnetosheath) of the sunward side of the magnetosphere.

2. General Description - A barium cloud release in the magnetosphere would be performed by a ground launched rocket (Scout) and the cloud would subsequently be observed and photographed from a space station in earth orbit (say 270 n.m. altitude). The camera mount would be driven by programmed servo motors to remain fixed on the plasma cloud during the necessary time exposures.

3. Operational Constraints - Camera must be capable of having a range of orientation such that it could remain fixed on a cloud at say 5 earth radii altitude for nearly one half of an orbital period.

4. Mode of Operation and Crew Support - Scientist-astronaut presets program for servo drive based on ground based computation and operates camera to photograph barium cloud.

5. Spacecraft Support - Photographic camera with pre-programmed servo driven mount. 6" f.L. f2 - 35#

6. Development Schedule and Costs -

70-71	Study
71-72	Camera and Mount
72-73	Space Station Hardware
	Scout rocket and barium payload

EXPERIMENT DATA SHEET

ELECTRON BEAM OBSERVATION EXPERIMENT

1. Specific Objective - To introduce an electron beam into the upper ionosphere and monitor its behavior so as to investigate the fundamental physics of collisionless beam-plasma interactions.

2. General Description - The presence of a collisionless ambient plasma in the upper ionosphere and the absence of wall effects makes it possible to investigate the basic physics involved in the creation of an energetic electron beam and its interaction with an ambient plasma. Such information provides insight into natural streaming processes such as the initiation of aurorac as well as providing design data for more advanced experiments using electron injection.

   In the present experiment a subsatellite containing an electron accelerator is launched from a manned station and is guided to a position in the upper ionosphere. At this point an electron beam is directed along the magnetic field and the subsequent growth of the beam and development of instabilities are monitored by spectrographic cameras, photographic cameras, and radio receivers on board the manned station. Electron cyclotron radiation from the unstable region at the front of the beam and bremsstrahlung when the beam finally impacts the denser ionosphere give information concerning the energetic processes occurring while the two kinds of cameras give information about the composition of the interaction region and the lateral diffusion of the beam.

3. Operational Constraint - Cameras and antennas must be oriented so as to keep the beam in view throughout the experiment.

4. Mode of Operation - Since radiations from the beam will probably be too weak to be observed from the ground, the use of a manned station is the most appropriate method of performing the experiment. The use of a subsatellite to support the electron accelerator could be replaced by direct ground launch but perhaps at some sacrifice in convenience if the experiment were to be repeated several times at various electron beam currents and energies.

5. Crew Support - If the subsatellite is used the scientist-astronaut will have to maneuver it into appropriate position and operate the cameras and radio monitoring equipment. If data reduction were to take place between experiments the astronaut would either have to lock and stow the subsatellite or performs station keeping maneuvers.

6. Spacecraft Support - Spectrographic and photographic cameras - 35#
0-6 M hz. radio receiver with antennas - 15#
Subsatellite electron acdelerator with power supply 1000#

7. Cost and Development Schedule

70-71	Study
71-72	Spectrographic and Photographic cameras
72-73	Electron accelerator and power supply
73-74	Space Station Hardware

EXPERIMENT DATA SHEET

PLASMA JET EXPERIMENT

1. Specific Objective To study the behavior of a plasma jet engine operating in the vacuum of space in order to understand better the pertinent plasma processes and to evaluate the device as a prototype of a station keeping thruster for advanced space projects.

2. General Description A plasma jet device is mounted on a manned space station and its operation is monitered by spectroscopic measurements and Langmuir probes located in the emitted plasma stream. The device will be capable of operating with various materials for propellants, e.g. cesium and/or barium, and will be capable of ejecting plasma continuously at a rate ranging from 0.01 gram/sec to 1 gram/sec. Continuous operation of such a device in earth based laboratories over extended periods is impossible because of the difficulty of maintaining hard vacuum under such conditions. Such vacuum is crucial for examining such aspects of the behavior as the separation of the emitted plasma from the magnetic field of the device. Information gathered from the experiment would illuminate the basic physics of plasma injection into a vacuum, and would also aid in development of similar devices for the deposition of alkali metal plasma clouds for use in magnetospheric or ionospheric studies. Also the variable density and thrust of the device make it a likely candidate for use as a station keeping thruster for advanced space projects.

3. Operational Constraints Virtually no constraints except that of earth orbit.

4. Mode of Operation Plasma jet engine would be mounted on manned station along with tanks containing various propellants to be used. The jet would be operated in various modes, both pulsed and continuous, and its operation would be monitered by spectrographic cameras placed so as to observe the lateral diffusion of the plasma beam. Langmuir probes would be located in the flow in the nozzle region in order to moniter plasma properties.

5. Crew Support Scientist-astronaut would operate thruster, adjust flow rates, change propellants, move probes at nozzle from time to time, operate spectroscopic camera, and moniter Langmuir probes.

6. Spacecraft Support The space station would need to provide about one KW of electrical power to the experiment, in addition to the following items:

Plasma jet device - 50# 0.5 ft^3

PLASMA JET EXPERIMENT (page 2)

Propellant storage - 10# 1.5 ft^3
D.C. power conditioning equipment - 50# 1.5 ft^3
or A.C. power conditioning equipment - 100# 1.5 ft^3
Spectroscopic Camera - 6# 0.25 ft^3
Langmuir probes and supports - 4#

7. COSTS AND SCHEDULES

70-71	Study
71-72	Prototype Hardware
72-73	Flight Hardware

EXPERIMENT DATA SHEET

PLASMA WAVE PROPAGATION EXPERIMENT

1. Specific Objective.-

   A) The larger plasma volume available from an orbiting spacecraft and lower frequencies involved (compared to laboratory experiments) would permit refined tests of warm magnetoplasma theory.

   B) The data accumulated would provide detailed information on the ionospheric plasma parameters.

2. General Description.- A pulsed swept-frequency transmitter sends out a burst of energy. A receiver tens of meters away records the received signal. Spectral analysis permits the tracing of the dispersion relation for the plasma. By varying the orientation of the antenna and geomagnetic field magnetic field effects can be recorded.

3. Operational Constraint. - A) Altitude in excess of 300 km. B) Transmitter/receiver must be movable so that various orientations with the geomagnetic field can be obtained. C) Pointing to a few degrees.

4. Mode of Operation.- Most easily done manned with a simple subsatellite.

5. Crew Support.- Scientist-astronaut aligns the antennas with respect to the local magnetic field and monitors apparatus.

6. Spacecraft Support

   Transmitter: Range .2-14 MH_Z

   (Isis A type) Sweep Rate 20 sec
   Pulse Rate 30 pps
   Power 130 W

   Received Sensitivity 1mV ; Wt-50#; PWR-20 watts
   Volume - 1/2 cubic ft.

   (Alouette II type)

   Antennas - Two 20 meters long, 1 cm radius, 13 meters apart

7. Cost and Schedules

69-70	Study
70-71	Instrument Prototype
71-72	Flight Hardware
72	Space Station Hardware

EXPERIMENT DATA SHEET

INVESTIGATION OF SPACECRAFT WAKE

1. Specific Objective.- To determine the electron and ion density and temperature profiles in the vicinity of a large spacecraft, and especially to examine the extent and structure of the wake of the S/C and of inflatable subsatellites.

2. General Description.- A small maneuverable sub-satellite, with appropriate electron and ion sensors, is used to obtain ionospheric wake data from an earth-orbital laboratory. Optical lighting would be used to obtain bearing information and a radar system, on the parent S/C, would be required to determine range.

3. Operational Constraints.- None required except that of earth orbit.

4. Mode of Operation.- A small maneuverable sub-satellite will be ejected from the parent S/C and maneuvered relative to it to obtain wake information. In addition, inflatable sub-satellites would be released from the parent S/C and the wakes from these more symmetrical bodies would be monitored by the maneuverable sub-satellite.

5. Crew Support.- Launch of sub-satellites, maneuvering during data taking, calibration and minor servicing of the monitering sub-satellite.

6. Spacecraft Support.- The manned S/C must provide a telemetry receiver to receive signals from the sub-satellite instruments and a command transmitter to provide command data to the sub-satellite. These requirements are not unique to these experiments, however, since the same equipment is needed to support the Meteorological objectives. The specific support required to accomodate this experiment include:

    wt. capability - Inflatable sphere - 55# total
                     Transmitter and receiver - less than 100#
    pwr. - 50 watts
    vol. - 3-1/2 ft^3

   for electron and ion sensors and data handling equipment.

7. Cost and Schedules

69-70	Study
70-71	Instrument Prototype
	Wake Body Inflatable Subsatellite
71-72	Flight Hardware
72	Test Instruments and Train Astronaut
72	Space Station Hardware

FUNCTIONAL PROGRAM ELEMENT IV

AIRLOCK EXPERIMENTS

1. DISCIPLINE - Space Physics

2. PROGRAM ELEMENT - Experiments requiring a scientific airlock.

3. REQUIREMENT

   a) Determine the extent to which spacecraft debris and coma affect astronomical and other optical experiments by reflecting sunlight or depositing material on optical surfaces.

   b) Perform certain other experiments requiring a scientific airlock and astronaut participation.

   c) Evaluate man's capability to perform scientific observations.

4. JUSTIFICATION

   a) Several experiments have been submitted to perform optical measurements that may be affected by solar light scattered from the debris surrounding the spacecraft. An evaluation of the intensity of the scattered light is necessary to determine the extent of this effect.

   b) It is necessary to determine the effect on optical surfaces due to deposition of spacecraft debris and gasses in order to plan for future systems involving optical systems, such as astronomical telescopes.

c) Certain experiments such as S018 (micro-meteoroids) and S063 (airglow) are related to the contamination experiments and in addition possess an intrinsic scientific interest.

d) These experiments, because of their requirement for deployment through the airlock, and astronaut operational requirements allow evaluation of man's capability to perform useful manipulative and scientific functions on future systems.

5. COMPONENT EXPERIMENTS

a) T027 CONTAMINATION MEASUREMENTS

b) T030 ENVIRONMENTAL COMPOSITION

c) S018 MICROMETEORITE

d) T025 CORONOGRAPH CONTAMINATION EXPERIMENTS

e) S073 GEGENSCHEIN/ZODIACAL LIGHT

f) S063 UV AIRGLOW HORIZON PHOTOGRAPHY

6. DESCRIPTION

An experiment description sheet is attached for the above experiments. The experiments are related because of that need for a scientific airlock, their relation to the optical contamination problem, or their relation to dim light photography. With the possible exception of T030 they all require recovery of either film or the entire instrument. There are also requirements for pointing the airlock toward the sun, the horizon, and the nadir.

The experiments generally require astronaut participation and attention for an orbit or more.

It is expected that experiments such as T027, T030 and T025 if successful during the first Workshop period (1970-1972) will not need to be repeated as experiments in a later time period, but similar instruments may be carried later as a monitor.

S018 and similar micrometeoroid experiments may be useful during the intermediate and space station periods for scientific information related to the origin of micrometeoroids. S063 may be repeated during the same periods because of its interest to upper atmosphere physics.

7. SPECIAL CONSIDERATIONS

These experiments all require a scientific airlock. S063 and S073 also require dousing the interior lights of the spacecraft. All experiments with the possible exception of T030 require return of film, tape, and in some cases the entire instrument. Most of the experiments require orientation of the airlock in some particular direction which may conflict with solar power requirements.

EXPERIMENT DATA SHEET

T-027 CONTAMINATION MEASUREMENTS EXPERIMENT

1. SPECIFIC OBJECTIVES

   A) To use a photometer to measure sky brightness due to solar light scattered from the debris around the spacecraft.

   B) To measure degradation of optical properties of sample materials exposed to exhaust control jet gasses and other contaminants outside the spacecraft.

2. GENERAL DESCRIPTION - A camera and a white light photometer will be used to map the sky brightness on the sunward hemisphere as a function of angle from the sun. The array of optical samples will be exposed for timed intervals so that optical degradation by contaminants may be assessed. The scientific airlock will be used for both measurements.

3. OPERATIONAL CONSTRAINTS - The photometer experiment is carried out in sunlight with the sun on the airlock side. Spacecraft altitude controlled to ±1°, 4° per hour max; 180° unobstructed field of view from airlock; sun-sensor indicator must be mounted so that pilot can see when sun is acquired.

4. MODE OF OPERATION - Both photometer and optical samples extended and recovered through airlock manually. Photometer angle changes and data recording manually performed or automatically programable. Sample array is to be returned to earth's surface.

5. CREW SUPPORT - As above in 4. One crewman for extension through airlock and photometer operation. A second crewman for spacecraft orientation. Desired operation is for two cycles of photometer for four orbits. Crew time requested is about 40 minutes for four orbits.

6. SPACECRAFT SUPPORT - Weight 60 lbs.

   Photometer - 40" x 9" x 9"

   Sample Array - 16" x 9" x 9"

   Camera film and optical samples to be returned to earth (26 lbs).

7. DEVELOPMENT SCHEDULE

   Def. - FY 68 & 69

   Dev. - FY 70

   FLT. - FY 70 & 71

   Data Analysis - FY 72

8. FUNDING

   FY 68 200K FY 150K FY 70 350K

   FY 71 200K FY 72 100K

EXPERIMENT DATA SHEET

T-030 ENVIRONMENTAL COMPOSITION

1. SPECIFIC OBJECTIVE - To measure the chemical composition of the contamination gasses surrounding the spacecraft at various distances and angles from the spacecraft.

2. GENERAL DESCRIPTION - A quadrupole mass spectrometer will be used through the scientific airlock if possible to perform the measurement.

3. OPERATIONAL CONSTRAINTS - Not known, but probably none.

4. MODE OF OPERATION - It is desired to extend the mass spectrometer box thru the airlock on a boom and perform measurements at several distances and angles relative to the spacecraft. The data will probably be collected on magnetic tape and returned by telemetry.

5. CREW SUPPORT - Not accurately known, but extension and retrieval through airlock for several cycles will be required.

6. SPACECRAFT SUPPORT

   Volume 40" x 10" x 10". If data tape is returned instead of telemetry 10" x 10" x 10" and six lbs. to be returned.

   power: 15 watts average, 150 watts peak.
   75 watt - hours required.

   data : 9 channels analog

   NOTE: Either experiment must be reduced in size or the scientific airlock must be enlarged.

7. DEVELOPMENT SCHEDULE

Def.	FY 69
Dev.	FY 69 & FY 70
Data Analysis	FY 70 & FY 71

8. COST

FY 70 0.7M FY 71 0.6M

EXPERIMENT DATA SHEET

S018 MICROMETEORITE EXPERIMENT

1.) SPECIFIC OBJECTIVES

a.) The purpose of the experiment is to expose control surfaces to micrometeorites impacts in order to measure their flux and size distributions and their chemical composition.

b.) This should provide information related to the origin and spatial distribution of the particles.

c.) The effect of meteoroids on optical and other spacecraft surfaces can also be determined.

2.) GENERAL DESCRIPTION - Samples will be collected in telescoping canisters which will be carried inside the capsule during launch and recovery and will be placed outside the spacecraft for collecting samples.

3.) OPERATIONAL CONSTRAINTS - No need for attitude control. A tumbling mode would be desirable. An airlock will be necessary to place the experiment in the collection mode.

4.) MODE OF OPERATION - An exposure time of 8 hours would be useful in either a continuous or intermittent mode. The scientific airlock will be required.

5.) CREW SUPPORT - The astronaut will place the collection canister in the collection mode thru the scientific air lock and retrieve experiment after 8 hours. This should require a day in training

and a few minutes of operation and documentation time at each handling.

6.) <u>SPACECRAFT SUPPORT</u> - 6 lbs, 120 cubic inches. Returned to Earth.

7.) <u>DEVELOPMENT SCHEDULE</u> - The instrument is currently ready for flight.

8.) <u>COST</u> - 300 K $

EXPERIMENT DATA SHEET

T025 CORONOGRAPH CONTAMINATION MEASUREMENTS

1. SPECIFIC OBJECTIVES

   a) To determine the presence of an induced atmosphere about the spacecraft during flight and to determine the changes in this atmosphere.

   b) To determine the nature and extent of the F corona about the sun.

2. GENERAL DESCRIPTION - A coronograph and camera system will be deployed from the scientific airlock and oriented toward the sun, within the pointing accurracy requirements. Photographs will be made of the sun's corona and up to 10° from the spacecraft sun line.

3. OPERATIONAL CONSTRAINTS - Attitude control for duration of picture taking should be within 10.1 degree unobstructed field of view 30° about earth sun line. Scientific airlock oriented toward sun.

4. MODE OF OPERATION - Coronograph and camera assembly is mounted in airlock by astronaut and operated manually. Film to be returned to earth.

5. CREW SUPPORT

   As noted in 4. above 40 minutes per orbit for 3 orbits.

6. SPACECRAFT SUPPORT

   Ascent: 25 lbs and 2115 cu. inches

   Descent: 2 lbs and 2064 cu. inches.

7. DEVELOPMENT SCHEDULE

FY 68&69	Definition
FY 69&70	Development
FY 71	Data Analysis

8. COST

FY 68	150K	FY 69	100K
FY 70	100K	FY 71	100K

EXPERIMENT DATA SHEET

S-073 GEGENSCHEIN/ZODIACAL LIGHT

1. SPECIFIC OBJECTIVE - To measure the surface brightness and polarization of the night sky light over as large a portion of the celestial sphere as possible, in wavelengths centered at 4300A and 5500A. Perform the same experiment with sunlight on the spacecraft to determine the extent and nature of the spacecraft corona.

These nighttime astronomical experiments will delineate the astronomical sources of light without confustion from the airglow layer. The spacecraft corona measurements will define the optical environment for daytime astronomy and navigation in spacecraft missions remote from the earth.

2. GENERAL DESCRIPTION - The experiment will consist of a combined camera photometer system packaged in a self-supporting unit and designed to be placed in the scientific airlock. The data will consist of photographs and digitized brightness and polarization data which will be recorded on the same film by being studied and the quantitative digitized data will give the absolute values of the brightness and polarization. The range of brightness which will be studied varies from about 10 to 10,000 10th magnitude stars per square degree. The polarization is expected to range from a few percent to 20 percent. The data will be analyzed by reading off the intensity data from the film, and correlating it with the positions indicated by the star fields photographed.

The astronaut will be used in this experiment to determine that the equipment is functioning properly and that the spacecraft is pointed to those regions of the sky which are deemed of most interest to this study. It is essential that the astronaut be well briefed on the observations of the experiment so that he may be in a position to modify the flight plan in case the original experiment cannot be carried out.

3. OPERATIONAL CONSTRAINTS - Equipment is to be recovered and returned to the PI, for Film Development, System Calibration, Data Reduction, and Evaluation. The allowable spacecraft motions should not exceed 5° per minute and is desirable to be only 1° per minute. Film temperature is critical; i.e. Same as operational film.

4. MODE OF OPERATION - During the performance of the experiment no extraneous light can be present. The astronomical experiment must be carried out within one week of new moon. Operation during the two weeks around full moon would be impossible.

The measurements require a total nighttime observation period of six hours. The daytime observations require a total of about one hour but it would be desirable to have two one-hour sets of observations or even more in order to investigate the variability of the spacecraft contamination corona.

5. CREW SUPPORT -

A) During the original design it is necessary that one astronaut be called in several times to assure the

compatibility of the experiment with the operational requirements. It is estimated that one day at three separate times would be required for this phase.

B) The astronaut actually involved in the flight operation should be briefed in detail by the principal investigator and the liaison astronaut described in (a) before the flight.

C) Debriefing in which the astronaut will describe to the liaison astronaut and the principal investigator the exact sequence of observations and will examine the films obtained to comment on such aspects as irregularities and timing of observations.

6. SPACECRAFT SUPPORT - Launch and return a 20 lb. instrument 500 in^3 in volume. Data will be recorded on film and will operate on internal power.

7. DEVELOPMENT SCHEDULE - The experiment can be delivered in CY 69.

8. COST - FY 69, 260 K; FY 70, 90K. (already funded?)

EXPERIMENT DATA SHEET

S063 UV AIRGLOW HORIZON PHOTOGRAPHY

1. SPECIFIC OBJECTIVES - To measure the altitude and intensities of the atmospheric airglow emission in the visible and ultra-violet. To determine mechanisms of the airglow emission and to determine if the method may reveal varying amounts of ozone and ozone clouds. To determine the height of the emission layers and, through a world wide survey, the possible variation of the airglow layers with upper atmosphere depth.

2. GENERAL DESCRIPTION - a Maurer camera will be used to photograph the horizon and atmosphere at several points in the orbit. The photographs will be made by an astronaut through a UV transmitting quartz window mounted in the airlock. The film must be returned from orbit.

3. OPERATIONAL CONSTRAINTS - On about 2 orbits the airlock with quartz window installed must be pointed toward the horizon at several azimuth angles and during sunlight toward the nadir.

   a) Study should be made to determine if such pointing requirements on this and other experiments conflicts with the need for power from the solar arrays on the OWS.

4. MODE OF OPERATION - Camera is operated manually by astronaut after installation of quartz window in airlock. Film must be returned from orbit.

5. CREW SUPPORT - Astronaut is required to operate camera on at least three orbits and to indicate via a voice tape recorder the areas and times of photography. Measuring of S/C to be

performed as noted in 3.

6. SPACECRAFT SUPPORT

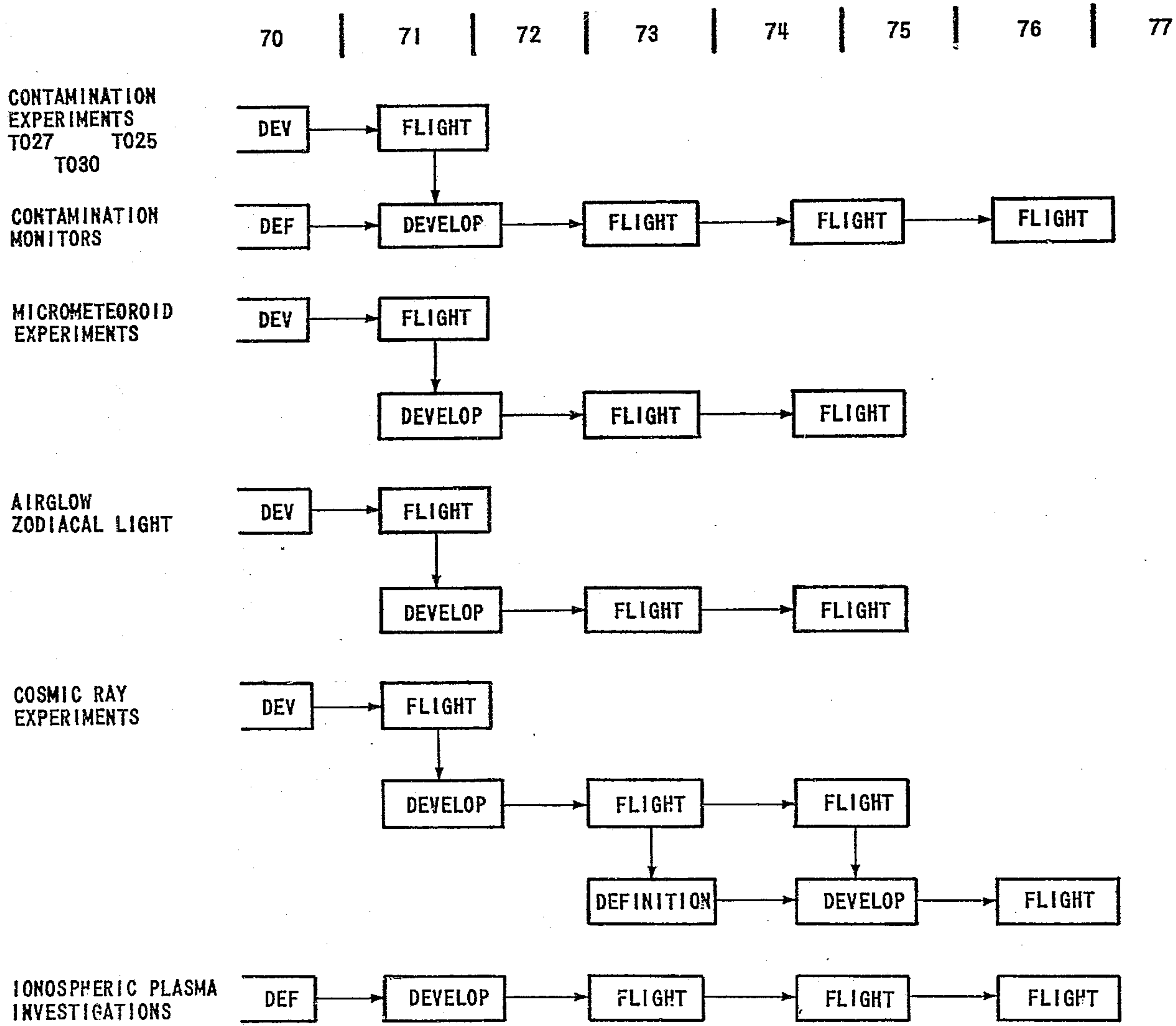
Ascent: 7 pounds and approx 140 cu. in.

Descent: Same.

7. DEVELOPMENT SCHEDULE - unknown

8. COST - unknown (already funded)

EVOLUTIONARY PLAN FOR SPACE PHYSICS



CONTENTS

CONTENTS (Cont'd)

SUMMARY

SPACE BIOLOGY

OBJECTIVES

To survey biological effects of weightlessness in Earth orbit on the physiology, morphology, and behavior of various organisms including primates, rodents, invertebrate animals, plants and single cell organisms by mid-1970's.

To survey effects on biological rhythms of removal from Earth's periodicities by Earth orbit space flight on organisms including rodents, insects, plants, and single celled organisms by mid-1970's.

To initiate studies in space flight on the mechanisms of, and the basis for, response and adaptation of organisms to weightlessness and removal from Earth's periodicities.

To develop the techniques and technologies for conduct of space biology experiments in manned space platforms.

To determine the means and extent of effective participation of scientific astronauts in space biology experimentation.

PROGRAM

The manned space flight space biology program will be a companion to the unmanned programs. Both programs will share the job of furnishing flight platforms for about 80 experiments (nominal objective). The manned flights are considered good candidates for either automated or partially automated experiments.

On the premise of increased overall capacities of the space stations and increased experience and know-how with space biology experimentation, it is expected that there will be greater use of scientist.astronauts in the experiment protocols toward 1974.

The experiments planned for the wet workshop will be largely automated, but will also begin to test man's ability to perform single laboratory tasks such as verifying the integrity of living systems in flight, recording physiological variables and focusing a microscope. Experiments in the intermediate period (1973-1975) will involve more elaborate measurements and minipulative skills. Some of them may also provide for tandem automated and astronaut-conducted experiments to allow comparison and evaluation of the effectiveness of the astronaut.

EXPERIMENT DEFINITION

The experiments tentatively earmarked for the manned program will be organized into five functional elements. A functional element may be a package or console containing modularized experiments or it may consist of several consoles thus permitting the distribution of a program element to several locations within a space station or even to different flights.

The following functional elements are planned:

	Vol.	Estimated Cost	Availability
Primates (Bio A)	1000 cu. ft.	$259 M	1974-1975
Microbiology (Bio C)	15 cu. ft	$12.9 M	1974-1975

Small Vertebrates (Bio D)	12 cu. ft.	\$13.3 M	1975
Plants (Bio E)	13 cu. ft.	12.8 M	1973-1974
Invertebrates (Bio F)	5 cu. ft.	\$ 9.3 M	1974-1975

FUTURE PROGRAM

In the post-1974 program most of the manned space biology experiments will be carried in the Biotechnology Laboratory. The Biotechnology Laboratory is conceived of as a life sciences laboratory occupying all or part of a manned space station or perhaps several space stations. It would provide a coordinated space laboratory facility for all of the life sciences activities of the agency including Bioscience, Biotechnology and Space Medicine. It is difficult to elaborate on this in terms of only Bioscie ce because the purpose will be to achieve maximum common use of skills and equipment for all of the life sciences work. In general the trend will be toward greater use of scientist-astronauts trained in the life sciences and more general purpose laboratory facilities. No doubt, special experiment packages will still be required with some degree of automation as dictated by the limited astronaut time, the peculiarities of the experiments and the nature of the spacecraft environment. It is in this laboratory and this time period that much of the "intensive" (as distinguished from "survey") experiments will be accomplished. Reusable adaptive equipment is contemplated which will permit repetition and variation of experiments without laborious development and integration work. Observations and procedures performed by the astronaut will be especially important for simplifying equipment, enhancing the flexibility of the experimental work, and for maximizing the scientific output.

The space biology experiment payload will consist of many experiments following the general functional element outline of the previous years, i.e., Bio A Primates, Bio C Microbiology, Bio D Small animals, Bio E Plants and Bio F Invertebrates. The functional elements will be so organized and designed to permit a wide variety of experiments in the same general areas with minimum equipment change. The experiments will be largely continuations of earlier experiments concentrating on intensive study of areas indicated by the earlier survey work, to offer the most promising rewards.

FUNCTIONAL PROGRAM ELEMENT I

PRIMATE (BIO A)

1. DISCIPLINE - Primate Physiology

2. PROGRAM ELEMENT - Primate (Bio A)

3. REQUIREMENT

To extend the study of primate physiology in weightless orbit beyond that accomplished in the Biosatellite.

4. JUSTIFICATION

a. Pure research to gain basic knowledge and theoretical understanding of physiological processes by use of the unique space environment; in particular to study the mechanism to response to gravity and Earth periodicities and to determine the effects of long-term confinement and the absence of sensory cues on the psychology and physiology in higher order primates. This is a search for fundamental knowledge which will utimately find use in biomedical research and applications.

b. To learn more about the time-course and extent of physiological and psychological changes and adaptation processes in higher order primates subjected to the space flight environment. This basic research will provide a good analytical understanding of the physiological responses and adaptations observed in astronauts which may be encountered during future space flights. It will provide the analytical basis for evaluation of untoward physiological effects that may occur

and for devising appropriate preventive measures.

c. To develop the techniques and technologies necessary to conduct analytical research on large animals in space. This will have particular value in the event that future manned experience indicates a need for more fundamental knowledge.

5. COMPONENT EXPERIMENTS

a. Physiology of Chimpanzees in Orbit.

b. The Hemodynamic and Metabolic effects of Weightlessness in Monkeys.

6. DESCRIPTION

Bio A consists of three primary modules, two of which will be approximately 15 feet long by 5 feet in diameter, cylindrical with spherical ends. One will be approximately 8 ft in diameter by 9 ft in length, cylindrical. The life support system (environmental control) will have to be carefully managed and measured by sensors and systems internal to the modules, however, the basic power, water, air, etc., will be supplied by the spacecraft. The modules will be in the nature of a quasi-plug-in design so that the modules could be fully checked out and installed at the launch facility, at the integration center or in-flight (via resupply mission).

7. SPECIAL CONSIDERATIONS

Return of animals and samples (urine and feces) as required. Acceleration must be held to a minimum compatible with manned flight.

NOTE: Bio A can be divided into three (or perhaps four) separate packages for flight on separate missions.

EXPERIMENT DATA SHEET

PHYSIOLOGY OF CHIMPANZEES IN ORBIT

A. Specific Objective

An intensive study of the behavior, the central nervous system and the cardiovascular system of chimpanzees in space flight.

B. General Description

This will be a combination of two experiments: one dealing with the central nervous system and behavior, and the other dealing with cardiovascular systems.

Both experiments will use the same primate subjects, which will be chimpanzees. One chimpanzee will be in semi-restraint and the other completely unrestrained. Each will be housed in a separate self-contained module or housing containing no orientation cues. Surface and deep brain probes will be employed to measure CNS electrical activity related to focused attention, drowsiness, fatigue, sleep, motor activity, visual acuity, and cardiovascular function. Other bioelectric sensors will monitor neuromuscular function in the neck and shoulder regions (EMG), eye movements (EOG), and galvanic skin resistance (GSR). The subjects will be presented with tracking problems to measure performance as well as simple tic-tac-toe type decision problems. The data collection protocol is such as to permit analysis for cyclic events (biological rhythms) as well as overall physiological and behavioral performance. Feces and urine from the restrained animal will be collected for general metabolic balance studies.

The same animals will be used simultaneously for cardiovascular studies. It is proposed that measurements be made of arterial and venous blood pressure, renal and pulmonary blood flow and electrocardiogram on the restrained and unrestrained animals. Measurements will be made with completely implanted sensors and telemetry. The cardiovascular data will be correlated with the electrophysiological, behavioral and performance data for an analysis of the effect of long-term space flight and confinement on higher order mammals.

C. Operational Constraints

Approximately zero g. No periodic cues.

D. Mode of Operation

The experiment will operate in the attached mode. It will be essentially self-contained within its own module. It will be highly automated but will make use of some manned functions. It will require continuous life support and relatively continuous communication, i.e. at least each orbit.

E. Crew Support

The planned crew support will consist of replacing consumables, removing samples and specimens,periodic checkout of electronics and replacing bug-in modules for maintenance and repair. The crew will also perform service in connection with the recovery of the animal. The time will consist of several hours a week. Special training and skills will relate to the equipment.

F. Spacecraft Support

Power - 2 kw avg. rate

Volume - 2 each, packages 5 ft. diameter by 15 ft. long cylinders with spherical ends.

Weight - Approximately 6000 pounds

Data - The telemetered data will be somewhere between 100 and 200 kilobits per second plus television, preferably commercial grade color TV. There will be 30 command channels.

G. Development Schedule

See Attached.

H. Cost

See Attached.

January 26, 1968

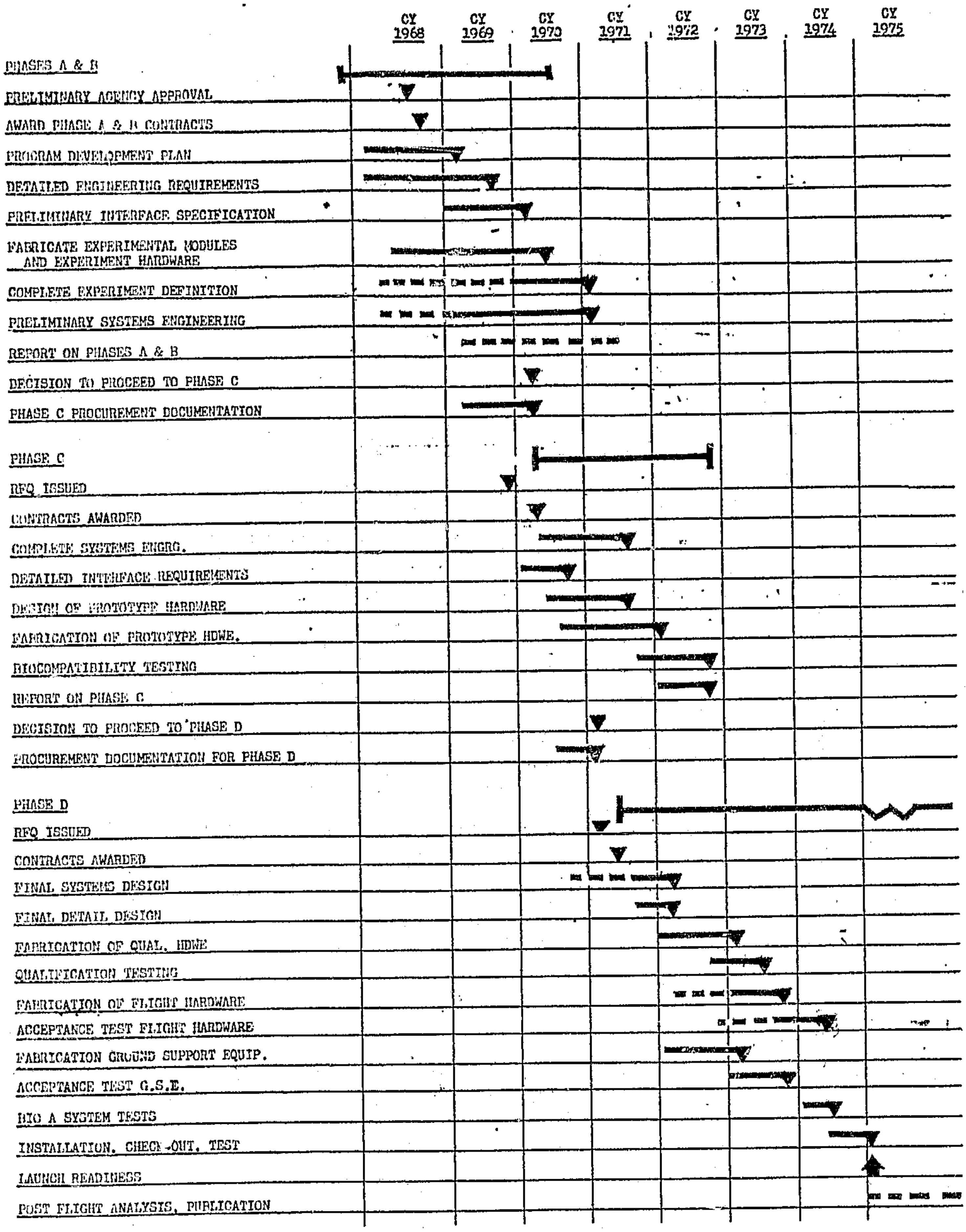
PRELIMINARY COST APPROXIMATION
FOR BIO A

	FY 1968	FY 1969	FY 1970	FY 1971	FY 1972	FY 1973	FY 1974	1975	1976	TOTAL
1. SR&T	2.3	2.1	2.3	2.0	1.0	1.0	1.0	1.0	1.0	13.7
2. Breadboard & Experimental Models		8.0	8.0	4.0						20.0
3. Prototypes & Specs for Flight Models			10.0	40.0	5.0					55.0
4. Flight Hdwe. and AGE				5.0	65.0	65.0	30.0			165.0
5. Integration				------Not Costed------						
6. Ground Operations and Data Acquisition							1.0	2.0		3.0
7. Data Analysis								1.0	1.0	2.0
TOTALS	2.3	10.1	20.3	51.0	71.0	66.0	32.0	4.0	2.0	258.7
PHASES A & B	←	$27.7M	→							
PHASE C				← $57.0M	→					
PHASE D					←		$174.0M		→	

NOTE: This cost estimate is for entire Bio A. Use ½ of each figure for the Chimpanze Experiment.

B10

January 26, 1968



EXPERIMENT DATA SHEET

THE HEMODYNAMIC AND METABOLIC EFFECTS OF WEIGHTLESSNESS ON MONKEYS

A. Specific Objectives

A comprehensive study of nutritional balance, metabolic activity, and hemodynamic function in two pig-tailed monkeys during a 60 day flight with appropriate pre- and post-flight studies.

B. General Description

This experiment will use two *Macaca nemestrina* pig-tailed monkeys, each contained in a separate closed module. The animals will be completely restrained and heavily instrumented. The metabolic measurements and analyses include total nutrient intake, waste production, respiratory gas exchange, heat production, insensible water loss, and body mass. The urinalysis will include the quantitative measurement of components associated with the stress syndrome. Hemodynamic measurement include somatic and pulmonary blood pressure, hemoglobin level, arterial and mixed venous oxygen tension, total volume, plasma protein level, EKG, and cardiac output.

The two monkeys will be identically instrumented and studied.

C. Operational Constraints

Approximately zero g. No periodic cues.

D. Mode of Operation

The experiment will operate in the attached mode. It will be essentially self-contained within its own module. It will be highly

automated but will make use of some manned functions. It will require continuous life support and relatively continuous communication, i.e., at least each orbit.

E. Crew Support

Functions:

Replace equipment modules on a repair and maintenance basis. Estimated Total Time: 20 hours. Duty Cycle: 20 minutes per day. Skill: Know equipment and operations -- engineering technician.

Change urine collector. Total Time: 40 hours. Duty Cycle: 4 times per day at 10 minutes. Skills: Same.

Change Feeding Tank. Total Time: 10 hours. Duty Cycle: One time per day at 10 minutes. Skills: Same.

Observe During Cardiac Output Determination. Total Time: 9.0 hours. Duty Cycle: 3 times per day at 30 minutes. Skills: Must know the experiment (scientist-astronaut-biologist). Special Training: Must work with experimenter and experiment development group for at least 6 months each.

F. Spacecraft Support

Random peak: 1100 watts. Average rate: 650 watts. Volume: 460 cubic feet. Cylinder: 96 in. diameter by 110 in. length. Weight: 4700 lbs. Other Interfaces: Vacuum (outlet to space). Heat sink: 2500 btu per hour at 40°Fahrenheit.
Data: 54 measurements, 100 samples per second peak at 6 bit resolution plus commercial grade TV preferably color TV.

G. Development Schedule

See Attached.

H. Cost

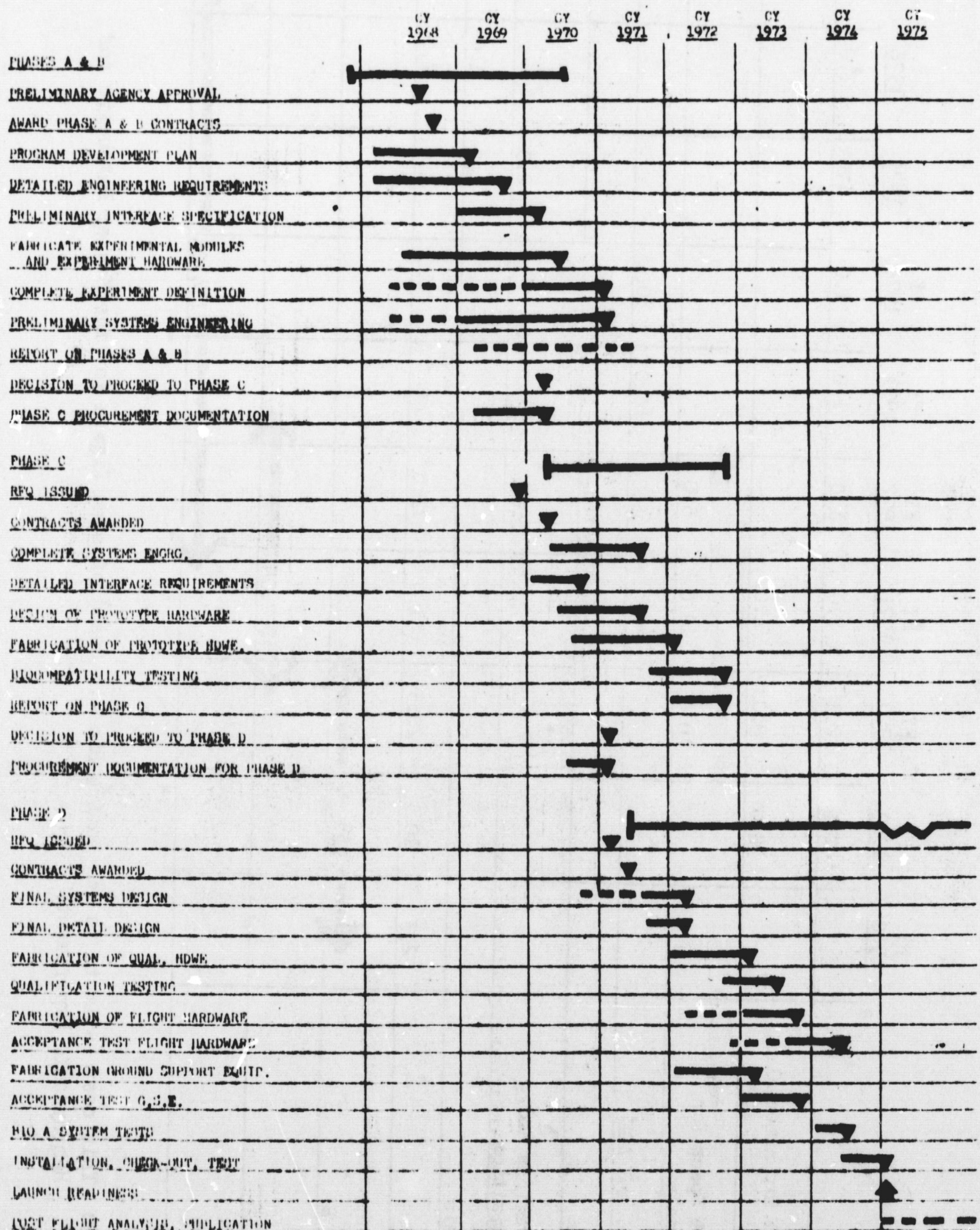
See Attached.

January 26, 1968

PRELIMINARY COST APPROXIMATION
FOR BIO A

	FY 1968	FY 1969	FY 1970	FY 1971	FY 1972	FY 1973	FY 1974	1975	1976	TOTAL
1. SR&T	2.3	2.1	2.3	2.0	1.0	1.0	1.0	1.0	1.0	13.7
2. Breadboard & Experimental Models		8.0	8.0	4.0						20.0
3. Prototypes & Specs for Flight Models			10.0	40.0	5.0					55.0
4. Flight Hdwe. and AGE				5.0	65.0	65.0	30.0			165.0
5. Integration				------Not Costed------						
6. Ground Operations and Data Acquisition							1.0	2.0		3.0
7. Data Analysis								1.0	1.0	2.0
TOTALS	2.3	10.1	20.3	51.0	71.0	66.0	32.0	4.0	2.0	258.7
PHASES A & B	←	$27.7M	→							
PHASE C				← $57.0M	→					
PHASE D					←		$174.0M	→		

NOTE: This cost estimate is for entire Bio A. Use ½ of each figure for the Monkey Metabolic and Hemodynamic Experiment.


CY 1968
CY 1969
CY 1970
CY 1971
CY 1972
CY 1973
CY 1974
CY 1975
PHASES A & B
PRELIMINARY AGENCY APPROVAL
AWARD PHASE A & B CONTRACTS
PROGRAM DEVELOPMENT PLAN
DETAILED ENGINEERING REQUIREMENTS
PRELIMINARY INTERFACE SPECIFICATION
FABRICATE EXPERIMENTAL MODULES AND EXPERIMENT HARDWARE
COMPLETE EXPERIMENT DEFINITION
PRELIMINARY SYSTEMS ENGINEERING
REPORT ON PHASES A & B
DECISION TO PROCEED TO PHASE C
PHASE C PROCUREMENT DOCUMENTATION
PHASE C
RFQ ISSUED
CONTRACTS AWARDED
COMPLETE SYSTEMS ENGRG.
DETAILED INTERFACE REQUIREMENTS
DESIGN OF PROTOTYPE HARDWARE
FABRICATION OF PROTOTYPE HDWE.
BIOCOMPATIBILITY TESTING
REPORT ON PHASE C
DECISION TO PROCEED TO PHASE D
PROCUREMENT DOCUMENTATION FOR PHASE D
PHASE D
RFQ ISSUED
CONTRACTS AWARDED
FINAL SYSTEMS DESIGN
FINAL DETAIL DESIGN
FABRICATION OF QUAL. HDWE
QUALIFICATION TESTING
FABRICATION OF FLIGHT HARDWARE
ACCEPTANCE TEST FLIGHT HARDWARE
FABRICATION GROUND SUPPORT EQUIP.
ACCEPTANCE TEST G.S.E.
BIO & SYSTEM TESTS
INSTALLATION, CHECK-OUT, TEST
LAUNCH READINESS
POST FLIGHT ANALYSIS, PUBLICATION

Appendix A

FUNCTIONAL PROGRAM ELEMENT II

MICROBIOLOGY (BIO C)

1. DISCIPLINE - Space Biology (Bioscience)
2. PROGRAM ELEMENT - Microbiology (Bio C)
3. REQUIREMENT

   Extend the survey and in-depth study of the role of gravity in the normal and abnormal functions of microorganisms, cells, tissues and semi-microscopic animals or plants by studying their responses to weightlessness, evolving from results gained in the Biosatellite Program toward plans for research in the Biotechnology Lab.

4. JUSTIFICATION

   a. The biological scientific community has identified a need for these data arising from both survey and in depth experimentation.

   b. The manned space flight and bioscience communities have endorsed this activity as a means for evolving a flexible, responsive, and powerful mode of carrying out research on the above test subjects in the Biotechnology Lab.

   c. The capability of long-term space systems to meet the environmental needs and the spacecraft support requirements must be evaluated in the operational environment, e.g., (1) provision of a very low acceleration environment; (2) isolation of microbiological experiments from rhythmic or cyclic phenomena.

   d. The ability of man to monitor, maintain and repair experiments and equipment must be demonstrated operationally. The capability

of the scientist/crewman must also be tested to determine whether he can (1) receive microbiological or other culture material, (2) prepare reusable or adaptable equipment for (3) in-flight set-up of experiments, (4) initiate new experiments, (5) remove, manipulate, and preserve samples, (6) modify experiment protocol and conditions as required by the P.I. and (7) terminate experiments, preparing appropriate material for logistics return. The requirement for, and role of, the microbiological specialist in a space station must be determined in operational tests.

e. Technological requirements must be satisfied (1) for the evolution of microbiological and other research equipment for incorporation in the Biotechnology Lab now under study by OART and (2) in the area of providing a low-g research environment free of rhythmic "cue" phenomena.

5. COMPONENT EXPERIMENTS

The experiment selections and descriptions given herein are only typical. They are in no way intended to indicate the final selections of formats. They are given here only to permit planners to assess the impact of a typical microbiological Functional Program Element on the total space flight system. The experiments comprising Bio C are grouped in seven areas characterized either by (1) potential for common use of same test individuals by a number of principal investigators, (2) unique importance of the biological area of interest or (3) unique environmental conditions required by the test subjects:

a. The role of gravity general cellular function.

(1) The effects of the space environment or general growth development behavior and reproduction of free cells.

(2) Maintenance of normal growth and reproduction of free cells in mass cultures in weightlessness over long periods of time.

(3) The effects of partial and complete weightlessness on development and maintenance of cell form and structure.

(4) The effects of partial and complete weightlessness on intermediary metabolism of cells.

(5) The effects of partial and complete weightlessness on mineral metabolism in cells.

b. The role of gravity in maintaining genetic stability in free cells.

(1) The effects of partial and complete weightlessness on mutation rates in microorganisms.

(2) The effect of hypogravity on mitotic malfunctions in free cells.

(3) The effect of the space environment on intranuclear metabolism in free cells.

c. The role of gravity in tissue function.

(1) The effect of partial and complete weightlessness on development and maintenance of hard tissues of vertebrates.

(2) The effect of hypogravity on soft tissues of animals.

(3) The effect of weightlessness on plant tissue growth, development and response to tumor-producing agents.

d. The role of gravity in maintenance of normal development in the animal embryo.

(1) The effect of weightlessness on functional and developmental stability of vertebrate embryos.

e. The role of gravity in the relationship of host and parasite.

(1) The effect of hypogravity on the course of parasitism among microorganisms.

f. The role of geophysical environmental factors in control of biorhythms in microorganisms.

(1) The effects of the space environment on perodicity of growth and conidial formation in fungae.

g. The role of gravity in interactions at the molecular level of cellular metabolism

(1) The effects of weightlessness on molecular level reactions *in vitro*.

6. DESCRIPTION

Bio C is a cluster of microbiological experiment modules grouped together on the basis of commonality in: equipment requirements, support requirements, research approaches, and specimen handling and observation techniques.

a. Approximate Characteristics

Weight: 107 lbs.

Volume: 10 cu. ft.

Power: 235 watts

Cost: $13.45M

b. Variable packaging geometry can be used.

c. Envelope is undefined. FPE Bio C can be deployed in an independent module developed for Bio E or possibly in the workstation developed for Bio D.

d. Individual experiment developments are independent of the development of both the space station and Bio C program element.

7. SPECIAL CONSIDERATIONS

a. Minimization of acceleration, vibration and noise in magnitude (or intensity), duration, and frequency of exposure (6 d.f.)* is required.

b. Continuous record of accelerations (6 d.f.) vibrations and noise is required. (See 7a)

c. Isolation from all periodic or rhythmic phenomena (vibration, noise, thermal, etc.) is required.

d. On-board centrifuge is desirable (0.1-1.0g) both as an on-board flight control and research tool.

e. Multipurpose photographic capability required for both microscopic

*Footnote: 6 degrees of freedom of acceleration; 3 translational plus 3 rotational.

and macroscopic objects in both planned and ad hoc research operations.

f. Real-time TV or near-real-time video tape capability desirable for ad hoc observation by ground based P.I. of experiment equipment, procedures, and both microscopic and macroscopic specimens.

g. The animal facility will require an environmental control system isolated from the spacecraft system to permit removal of specimens from their housing for transfer, research procedures or logistics preparation.

h. Scientist-astronaut work space for manipulation of experiments, ancillary equipment and specimens must be provided as a part of the FPE. Capability to pressurize the workspace to sea level atmospheric conditions must be provided if on-board scientist is to manipulate specimens in the workspace outside of their containers. Appropriate operational doctrine to permit scientist to do useful work during his decompression periods must be developed.

i. The animal facility will be either internal to the space station or permanently docked.

j. A data handling system common within the Functional Program Element would be desirable to link the experiment sensors through the FPE, through the space station Data Management System to Earth.

k. A common use specimen preservation system would be desirable for freezing or freeze-drying specimens for return to Earth at the usual logistics intervals.

1. Automatic reentry capsules will be desired for return of specimens, photographs, records or total experiment packages.

EXPERIMENT DATA SHEET

THE ROLE OF GRAVITY IN GENERAL CELLULAR FUNCTION

---The effects of the space environment on general growth development behavior and reproduction of free cells.

---Maintenance of normal growth and reproduction of free cells in mass culture in weightlessness over long periods of time.

---The effects of partial and complete weightlessness on development and maintenance of cell form and structure.

---The effects of partial and complete weightlessness on intermediary metabolism of cells.

---The effects of partial and complete weightlessness in mineral metabolism in cells.

1. SPECIFIC OBJECTIVE

The experiments are designed to shed light on the role of gravity in normal and abnormal cellular function by placing normally free-living or experimentally isolated cells in a hypogravic environment and observing the means by which they adapt to, or are impacted by, the abnormal environment. Detailed study of cells' deviations from the 1-g norm will provide insight into the role of gravity under normal conditions, unachievable by other means.

2. GENERAL DESCRIPTION

The experiments are designed to observe the influence of zero gravity on individual cells; observing at least the following states: The capacity of the cell to maintain its cytoplasmic membrane, to maintain its constant

reversibility of the cytoplasm sol-gel to take in food, to avoid irritant stimuli, and to undergo normal mitotic cycles. Details of these functions may be accomplished by observing pinocytosis, phagocytosis, locomotor behavior, mitochondrial motion, chromosomal generation, and separation.

Studies on growth of small populations of microorganisms in the convection-free environment of hypogravity will be carried out to determine limiting phenomena in the environment. The results will prepare the way for applied experiments in maintaining normal growth metabolism and reproduction of mass cultures of free cells such as algae or Hydrogenomonas. Data from these applied experiments will serve as the basis for bioregenerative life support systems.

Detailed metabolic studies of the carbohydrate and protein intermediary metabolism of free cells will be used to interpret deviations from 1-g norms in studies cited above. Studies of mineral metabolism of certain microorganisms may be used to understand the mechanisms of mineral metabolism in 1-g as well as changes observed in higher organisms exposed to the weightless environment.

Experimental approaches will include various forms of microscopy, time lapse photography, solution densitometry, and a wide array of biochemical analyses. Subcultures for post flight study and killed, fixed specimens will be returned.

3. OPERATIONAL CONSTRAINTS

Acceleration environment is critical. Engineering solutions to minimize g-forces can be achieved. Altitude, inclination, pointing not critical. Must be isolated from any periodical phenomena.

4. MODE OF OPERATION

   A. Man attended.

   B. If attached: isolated from S/C acceleration.
      If detached: dockable for man access.

   C. Continuous operation.

5. CREW SUPPORT

   A. Functions: set up experi[illegible]onitor; maintain and repair; focus microscope; operat[illegible]; inject fluids into chambers; subculture by aliquot transfer; simple biochemical analysis; sample preparation for logistics return; experiment termination.

   B. Time set up: 1 hour per experiment

      Experiment operations: 1 hour per experiment per day

      Terminate: 2 hours per experiment

   C. Duty cycle: once per day; 90 days; number of simultaneous experiments to be determined.

   D. Skills: (see 5A)

   E. Special training: Equivalent to laboratory assistant, plus <u>ad hoc</u> training with P. I.

6. SPACECRAFT SUPPORT

   A. Power 50 watts average

   B. Volume 2 ft^3

   C. Weight 25 lbs.

   D. Envelope Rectangular

   E. Data Film and specimens to be recovered; total S/C environment including acceleration.

7. DEVELOPMENT SCHEDULE

Phase A	Phase B	Phase C	Phase D
FY '70	FY '71	FY '72	FY '73-'74

8. COST - COSTS INCLUDE ONLY EXPERIMENT DEVELOPMENT
Total Cost $3.0M

FY '70	FY '71	FY '72	FY '73	FY '74
200 K	400 K	700 K	900 K	900 K

EXPERIMENT DATA SHEET

THE ROLE OF GRAVITY IN MAINTAINING GENETIC STABILITY IN FREE CELLS

---The effects of partial and complete weightlessness on mutation rates in microorganisms.

---The effect of hypogravity on mitotic malfunctions in free cells.

---The effect of the space environment on intranuclear metabolism in free cells.

1. SPECIFIC OBJECTIVE

Biosatellite results have indicated organisms in the weightless state are more prone to genic or chromosomal aberrations than those in 1-g. The goal of these experiments is to understand the mechanism by which this phenomenon occurs.

2. GENERAL DESCRIPTION

Basic studies of mutation rates in free cells will be undertaken in the weightless environment by exposure to combinations of the hypogravic state with other known mutagenic factors. Rates at which mutants are produced can be determined by qualitative or quantitative measurement of abnormal metabolic end products, differentiating from "normals," or by detection of "marker" characteristics of growth, form, etc.

In similar fashion combinations of these identifying characteristics can be employed to detect mitotic malfunctions such as chromosome breakage and recombination in abnormal fashion. The anomalous effects of weightlessness on such sensitive cellular periods as meiosis and mitosis can easily be determined.

The biochemical and biophysical events underlying the production of

these anomalies and the role of gravity in averting them on Earth may be best understood by studies in depth of nucleic acid metabolism and related intranuclear activities. Labeling and other biophysical and biochemical techniques can be used both on board the space craft and post flight to trace the metabolic chain of events taking place during the weightless period.

3. OPERATIONAL CONSTRAINTS - Acceleration environment is critical. Engineering solutions to minimize g-forces can be achieved. Altitude, inclination, pointing not critical. Must be isolated from any periodical phenomena.

4. MODE OF OPERATION

A. Man attended.

B. If attached: isolated from S/C acceleration.

C. Continuous operation.

5. CREW SUPPORT

A. Functions: Set up experiment, monitor; maintain and repair; focus microscope; operate camera subculture by aliquot transfer; simple biochemical analysis; isotope tracer techniques; sample preparation for return; experiment termination.

B. Time: Experiment set up - 1 hour per experiment.
Experiment operation - 2 hours per experiment per day.
Experiment termination: 2 hours per experiment.

C. Duty cycle: Once per day; 90 days; number of simultaneous experiments to be determined

D. Skills: see 5A

E. Special Training: Equivalent to laboratory assistant plus *ad hoc* training with P. I.

6. SPACECRAFT SUPPORT

A. Power 50 watts average

B. Volume 1.0 $ft.^3$

C. Weight 12 lbs.

D. Envelope TBD

E. Data Recovered specimens; total S/C environment (including accelerations)

7. DEVELOPMENT SCHEDULE

Phase A	Phase B	Phase C	Phase D
'70	'71	'72	'73

8. COST - COSTS INCLUDE ONLY EXPERIMENT DEVELOPMENT

Total $2.2 M

FY	'70	'71	'72	'73	'74	Flight
$K	200	300	400	600	590	200

EXPERIMENT DATA SHEET

THE ROLE OF GRAVITY IN TISSUE FUNCTION

---The effect of partial and complete weightlessness on development and maintenance of hard tissues of vertebrates.

---The effect of hypogravity on soft tissues of animals.

---The effect of weightlessness on plant tissue growth, development and response to tumor-producing agents.

1. SPECIFIC OBJECTIVE

1. By placing test speciment in an environment known to cause a unique form of abnormal bone metabolism (calcium loss) to (a) understand more clearly the normal metabolism of bone and (b) to understand the mechanism by which the abnormality can be averted.

2. By exposing plant tumor tissue cultures in hypo-gravic conditions, to understand the mechanism of growth of these abnormalities.

2. GENERAL DESCRIPTION

Selected bony tissues will be grown in vitro in the weightless state. Time lapse photography, weight and size measures, histological and biochemical analyses of the test specimens during and post flight will be performed to compare flight samples and ground controls.

Demineralization of bone is regulated by hormones. In order to understand the metabolism of bone and demineralization in space, it is necessary to study the soft glandular tissue producing these hormones. Exposure of cultures of these tissues in the weightless state, in various culture media, followed by well established biochemical and biophysical

measures relating hormone output with degree of demineralization, should clarify many aspects of both normal and abnormal mineral metabolism.

Studies of plant tissues in the weightless environment rank equal in importance to those of animal tissues in terms of economic implications. Plant tissue cultures, often called callus cultures, are masses of parenchyma of vascular plants which are derived from stems, roots, fruits by growing portions of these organs in sterile culture medium containing relatively high concentrations of auxin, or auxin-like compounds, certain herbicides, and sometimes compounds of unknown nature in malt extract. A similar effect has often been produced by infection of host plant parts with tumefacient bacteria: after the bacteria disappear the resultant gall may be grown axenically as a callus culture. These treatments cause the tissues to lost their polarity and to grow equally in all directions. Metabolites, minerals, water, etc., must be transported through parenchyma of such callus against the force of gravity. The callus cultures will be grown in pyrex glass culture tubes. No light is necessary, except when the cultures are monitored and photographed at daily intervals. The tissues will be grown upon the foods, minerals, water, etc., contained in the agar culture medium, and will not depend upon photosynthesis for their metabolism. The pattern and quantity of growth will be recorded by the onboard scientist/astronaut.

3. <u>OPERATIONAL CONSTRAINTS</u> - Acceleration environment is critical. Engineering solutions to minimize g-forces can be achieved. Altitude, inclination, pointing not critical. Must be isolated from any periodical phenomena.

4. MODE OF OPERATION

A. Man attended.

B. If attached: isolated from S/C acceleration.
If detached: dockable for man access.

C. Continuous operation.

5. CREW SUPPORT

A. Functions: set up experiment; monitor; maintain and repair; operate microscope and camera; remove samples; simple biochemical analysis; sample preparation for logistics returns.

B. Time: Set up: 1 hr. set up.

Experiment operations: 1 hr. per day per experiment.

Terminate: 2 hrs. per experiment.

C. Duty cycle: Once per day; 90 days; number of simultaneous ex-experiments to be determined.

D. Skills: See 5A

E. Special training: Equivalent to laboratory assistant, plus *ad hoc* task training with P. I.

6. SPACECRAFT SUPPORT

A.	Power	75 watts
B.	Volume	3 ft^3
C.	Weight	20 lbs.
D.	Envelope	TBD
E.	Date	Recovered specimens and film; total S/C environment (including accelerations)

7. DEVELOPMENT SCHEDULE

Phase A	Phase B	Phase C	Phase D
'70	'71	'72	'73-'74

8. COST - COSTS INCLUDE ONLY EXPERIMENT DEVELOPMENT

	FY '70	'71	'72	'73	'74	Flight
$(K)	200	300	400	600	500	200

Total Cost ($2.2M)

EXPERIMENT DATA SHEET

THE ROLE OF GRAVITY IN MAINTENANCE OF NORMAL DEVELOPMENT IN THE ANIMAL EMBRYO

---The effect of weightlessness on functional and developmental stability of vertebrate embryos.

1. SPECIFIC OBJECTIVE

Detect the effect of weightlessness and radiation combined with weightlessness on vertebrate embryos.

2. GENERAL DESCRIPTION

While this study might well be included under Bio D (Small Vertebrates) the rearing of small avian embryos lends itself to the equipment used for microbiological or tissue culture studies.

Initial experiments would be simple, merely exposing suitable eggs to weightlessness and radiation singly or in combination. Standard embryological and histological techniques will serve to detect any anomalies present. Follow-on experiments,, again very simply conducted, would permit focussing on specific anomalies of interest, characterizing them in depth and exploring mechanisms by which they arise. Metabolic studies added at this time would increase the scope of understanding of the phenomena involved.

The desirability of avian species as test animals lies in the ease with which embryos can be handled and the excellence of the baseline data available as background.

3. OPERATIONAL CONSTRAINTS - Acceleration environment is critical. Engineering solutions to minimize g-forces can be achieved. Attitude, inclination, and pointing are not critical. Must be isolated from any periodical phenomena.

4. MODE OF OPERATION

A. Man attended.

B. If attached: isolated from S/C acceleration

C. Continuous operation

5. CREW SUPPORT

A. Functions:	Set up experiment; monitor; maintain and repair; operate photomicrography equipment; simple biochemical analysis; isotope tracer monitoring; sample fixation and preparation for return; terminate experiment.
B. Time:	Experiment set up-1hour per experiment Experiment operation-2hours per day per experiment Experiment termination-2hours per experiment
C. Duty Cycle:	Once per day; up to 90 days; one experiment at a time
D. Skills:	See 5.A.
E. Special Training:	Equivalent to laboratory assistant plus ad hoc training with P.I.

6. SPACECRAFT SUPPORT

A. Power	25 watts average
B. Volume	1.0 ft^3
C. Weight	15 lbs
D. Envelope	TBD
E. Data	Recovered specimens, film and total S/C environment (including acceleration)

7. DEVELOPMENT SCHEDULE

	Phase A	Phase B	Phase C	Phase D
FY	'70	'71	'72	'73-'74

8. COST Total $1.4 M (Includes only experiment definition and development)

FY	'70	'71	'72	'73	'74	Flight
$ (K)	100	150	250	400	400	100

4. MODE OF OPERATION

A. Man attended.

B. If attached: isolated from S/C acceleration.
If detached: dockable for man access.

C. Continuous operation

5. CREW SUPPORT

A. Functions: Set up experiment; monitor; maintain and repair; operate photomicrography equipment; simple biochemical analysis; isotope tracer monitoring; sample fixation and preparation for return; terminate experiment.

B. Time: Experiment set up- 1 hour per experiment
Experiment operation - 2 hours per day per experiment
Experiment termination - 2 hours per experiment

C. Duty cycle: Once per day; up to 90 days; one experiment at a time

D. Skills: See 5.A.

E. Special training: Equivalent to laboratory assistant plus ad hoc training with P.I.

6. SPACECRAFT SUPPORT

A. Power	25 watts average
B. Volume	1.0 ft^3
C. Weight	15 lbs
D. Envelope	TBD
E. Data	Recovered specimens, film and total S/C environment (including acceleration.

7. DEVELOPMENT SCHEDULE

	Phase A	Phase B	Phase C	Phase D
FY	'70	'71	'72	'73-'74

8. COST Total $1.4 M (Includes only experiment definition and development)

FY	'70	'71	'72	'73	'74	Flight
$(K)	100	150	250	400	400	100

EXPERIMENT DATA SHEET

The Role of Gravity in Host Parasite Relationships.

--The effect of hypogravity on the course of parasitism among microorganisms.

1. SPECIFIC OBJECTIVE

The objective of these studies is to detect the effect, if any, of weightlessness, upon host-parasite relationship seen in microorganisms.

2. GENERAL DESCRIPTION

Standard test organisms, such as bacteria of choices, would be exposed to attack by typical parasites; e.g. phage or other parasitic bacteria both in the weightless environment and in 1-G environment of Earth. Growth curves developed from inflight measurements of turbidity can be used to assess the rate of attack by the parasite.

Samples preserved for on-board and post-flight analysis would provide data on the mechanisms involved.

3. OPERATIONAL CONSTRAINTS - Acceleration environment is critical. Engineering solutions to minimize g- forces can be achieved. Altitude, Inclination, pointing not critical. Must be isolated from any periodical phenomena.

4. MODE OF OPERATION

A. Man attended.

B. If attached: isolated from S/C acceleration.

If detached: dockable for man access

5. CREW SUPPORT

A. Functions: Set up experiments; monitor; maintain and repair fluids handling; sampling for subculture sample

preservation for return; experiment termination.

B. Time: Experiment Set up; 1 hour per experiment.

Experiment Operations: 2 hours per experiment.

C. Duty Cycle: Once per day; 90 days; number of simultaneous experiments to be determined.

D. Skills: See 5.A.

E. Special Training: Equivalent to laboratory assistant, plus *ad hoc* training with P.I.

6. SPACECRAFT SUPPORT

A. Power 15 watts average

B. Volume 1.0 $ft.^3$

C. Weight 15 lbs.

D. Envelope TBD

E. Data Recovered specimens in total spacecraft environment (including acceleration)

7. DEVELOPMENT SCHEDULE

Phase A	Phase B	Phase C	Phase D
FY '70	FY '71	FY '72	FY '73-'74

8. COST Total 1.7 M (Includes Only Experiment Definition and Development)

FY '70	FY '71	FY '72	FY '73	FY '74	Flight
150	200	300	500	400	150

EXPERIMENT DATA SHEET

THE ROLE OF GEOPHYSICAL ENVIRONMENTAL FACTORS IN CONTROL OF BIORHYTHMS IN MICROORGANISMS

---The effects of the space environment on periodicity of growth and conidial formation in fungi.

1. SPECIFIC OBJECTIVE:

Detect specific rhythm-environment coupling, if they exist, for fungi and to explore the mechanism of this coupling in depth.

2. GENERAL DESCRIPTION:

Strains of the pink bread mold Neurospora which show clear-cut circadian rhythms of growth and sporulation are available. These physiological phenomena are endogenous and genetically controlled. The three different strains, "wristwatsh," "clock" grandfather clock" vary in amplitude from .20cm to 1.6cm of growth per day. It is not known whether the periodicity of conidial formation and growth, given a standardized environment e.g., temperature, medium, etc., is an earth-bound phenomenon. The effect of zero gravity, acceleration, weaker magnetic fields, "abnormal day" (an approximate 90 minute period for circling the earth) etc., might alter the periodicity. Several tubes of each of four strains of different rhythmic patterns will be employed. The entire experiment would be photographed at 2 or 3 hour intervals. The periodicity and growth rate of the orbiting samples will be compared with that of samples kept on earth utilizing a standard environment.

3. OPERATIONAL CONSTRAINTS:

Acceleration environment is critical. Engineering solutions to minimize g-forces can be achieved. Altitude, Inclination, pointing not critical. Must be isolated from any periodical phenomena.

4. MODE OF OPERATION:

A. Man attended, but largely automatic

B. If attached: isolated from S/C acceleration
If detached: dockable for man access.

C. Continuous operation

5. CREW SUPPORT:

A.	Functions:	Setup experiment; monitor; maintain and repair; Photograph culture tubes; subculture for followon experiments; sample preservation and preparation for return; terminate experiment.
B.	Time Experiment set up Operations:	1 hr. per experiment 15 minutes per photo, per experiment
C.	Duty Cycle:	8 times per day per experiment 90 days; number of experiments to be determined.
D.	Skills:	See 5.A.
E.	Special Training:	Equivalent to laboratory assistant, plus *ad hoc* task training with P.I.

6. SPACECRAFT SUPPORT:

A.	Power	10 watts average
B.	Volume	1 ft^3
C.	Weight	5 lbs.
D.	Envelope	TBD
E.	Data	Samples and film to be recovered. Growth determined from film and telemetered to earth. Total S/C environment (including accelerations).

7. DEVELOPMENT SCHEDULE:

	Phase A	Phase B	Phase C	Phase D
FY	'70	'71	'72	'73-'74

8. COST: Total $1.550M(Includes only experiment definition and development)

FY	'70	'71	'72	'73	'74	Flight
$ (K)	150	200	300	400	400	100

EXPERIMENT DATA SHEET

THE ROLE OF GRAVITY IN INTERACTIONS AT THE MOLECULAR LEVEL OF CELLULAR METABOLISM

---The effects of weightlessness on molecular reactions in vitro.

1. SPECIFIC OBJECTIVE

To determine the effects, if any, of weightlessness upon interactions of large molecular aggregates at the subcellular level.

2. GENERAL DESCRIPTION

Theoretical considerations indicate that gravity should not be a significant factor affecting subcellular, and particularly macromolecular phenomena. On the other hand, ground experiments suggest that in laminar flow systems, gravity does indeed exert an effect on very high weight macromolecules.

It is a point of key experimental significance to experimentors investigating cellular-level effects in weightlessness to confirm either the theory or the experimental inference.

A family of such (laminar flow) devices could be flown at a number of levels of hypogravity. Simple colorimetric measurements, photographs and returned samples would be requires to assess the results and compare with 1 g controls.

3. OPERATIONAL CONSTRAINTS

Acceleration environment is critical. Engineering solutions to minimize g-forces can be achieved. Altitude, inclination, pointing not critical. Must be isolated from any periodical phenomena.

4. MODE OF OPERATION

A. Man attended.

B. If attached: isolated from S/C acceleration.
If detached: dockable for man access.

C. Continuous operation.

5. CREW SUPPORT

A. Functions: Set up experiments; monitor; maintain and repair; fluid handling sample aquilots for preservation and return; terminate experiments.

B. Time: Experiment set up: 1 hr. per experiment

Experiment operations: 2 hrs. per experiment per day

Experiment termination: 2 hours per experiment

C. Duty cycle: Once per day; 90 days; one experiment at a time.

D. Skills: See 5A

E. Special training: Equivalent to laboratory assistant, plus *ad hoc* training with P. I.

6. SPACECRAFT SUPPORT

A. Power 10 watts average

B. Volume 1.0 ft^3

C. Weight 15 lbs.

D. Envelope TBD

E. Data Recovered specimens, total S/C environment (including acceleration)

7. DEVELOPMENT SCHEDULE

Phase A	Phase B	Phase C	Phase D
FY '70	'71	'72	'73-'74

8. COST - COSTS INCLUDE ONLY EXPERIMENT DEVELOPMENT

Total $1.4 M

FY	'70	'71	'72	'73	'74	Flight
$K	100	150	250	400	400	100

FUNCTIONAL PROGRAM ELEMENT III

SMALL VERTEBRATES (BIO D)

1. DISCIPLINE - Space Biology (Bioscience)

2. PROGRAM ELEMENT - Small Vertebrates (Bio D)

3. REQUIREMENT

Extend the survey and in-depth study of the responses of small vertebrate animals to weightlessness (free fall), evolving from results gained in ground based studies and in previous flights toward plans for research in a Manned Space Station.

4. JUSTIFICATION

a. The biological scientific community has identified a need for these data arising from both survey and in-depth experimentation.

b. The manned space flight and bioscience communities have endorsed this activity as means for evolving a flexible, responsive, and powerful mode of carrying out research on the above test subjects in a Manned Space Station.

c. The capability of long-term space systems to meet the environmental needs and the spacecraft support requirements must be evaluated in the operational environment, e.g., (1) provision of a very low acceleration environment; (2) isolation of certain vertebrate animal experiments from rhythmic or cyclic phenomena.

d. The ability of man to initiate, monitor and terminate experiments as well as to maintain and repair equipment must be

demonstrated operationally. For example, the capability of the scientist/crewman must also be tested to determine whether he can (1) receive test animals, tissues or cell preparations; (2) perform in-flight experimental preparation of animals and other test material for (3) installation in on-board experiment modules; (4) make direct observations, photographs or recordings on the test subjects; (5) perform various specimen collection and preservation techniques including biopsy, body fluid sampling, sacrifice and dissection; (6) make serendipitous or <u>ad hoc</u> demand observations; (7) modify experiment protocol and conditions as required; and (8) terminate animal experiments preparing both live specimens and preserved material for logistics return. The requirement for, and role of, an animal physiology specialist in a space station must be determined in operational tests.

e. Technological requirements must be satisfied (1) for the evolution of small animal research equipment for incorporation in the "Biotechnology Lab" now under study by OART; and (2) in the areas of providing a low-g research environment free of rhythmic "cue" phenomena.

5. <u>COMPONENT EXPERIMENTS</u>

The experiment selections and descriptions given herein are only <u>typical</u>. They are in <u>no way</u> intended to indicate the final selections or formats. They are given here only to permit

planners to assess the impact of a typical animal research Functional Program Element on the total space flight system. The experiments comprising Bio D are grouped in eight areas characterized either by (1) potential for common use of same test individuals by a number of principal investigators, (2) unique importance of the biological area of interest or (3) unique environmental conditions required by the test subjects:

a. The role of gravity in cardiovascular function.
   (1) Circulatory adaptation in rats during long-term weightlessness.
b. The role of gravity in embryogenesis, parturition, growth, development, metabolism and aging in rodents.
   (1) Pregnancy and oestrous cycle in the orbiting rat.
   (2) Differentiation and development in mammals conceived under conditions of zero-gravity.
   (3) Growth and behavior of individuals born in space and of those born on the Earth.
   (4) Effects of weightlessness on the development of the vestibular apparatus in mice.
   (5) The effects of weightlessness on central nervous system development.
   (6) The effect of weightlessness upon food intake regulation in normal and mutant mice.
   (7) Turnover of mineralized tissues.
   (8) Metabolic adaptation to prolonged space flight.

(9) Utilization of depressed metabolism in mammals during space flight.

(10) Exercise as a countermeasure to muscle and bone atrophy in space.

(11) Effect of weightlessness on the accumulation of aging pigment on nerve cells and heart muscle of rats.

c. The role of gravity in immune responses of mammals.

(1) Effects of weightlessness and ionizing radiation upon mobile cells and mucoprotein of interstitial substance in mammals.

(2) The effect of weightlessness on the immune response of mammals.

d. The role of gravity in embryogenesis and development in Amphibia.

(1) The effect of sub-gravity on the frog egg, fertilized and developing in space.

e. The role of gravity in growth and metabolism in reptiles.

(1) Influence of low gravity upon turtle growth and metabolism.

f. The influence of gravity on behavior in mammals.

(1) Orbiting behavioral centrifuge.

g. The influence of geophysical factors on biorhythms in vertebrates.

(1) Effects of the Earth orbital environment on biorhythms in the rat.

(2) Effect of gravity on biorhythms of animals.

h. The role of gravity in hibernation.

(1) Central nervous system functioning in hibernating or hypothermic marmots at zero gravity.

6. DESCRIPTION

Bio D is a cluster of small animal experiment modules grouped together on the basis of commonality in: equipment requirements, support requirements, research approaches, and specimen handling and observation techniques.

a. Approximate Characteristics

(1) Employing on-board centrifuge:

(a) Weight: 945 lbs.

(b) Volume: 103.7 ft^3

(c) Power:

(i) Average: 515 watts

(ii) Peak: 675 watts

(d) Cost: 13.65 M

(2) 0-g Program Only

(a) Weight: 530 lbs.

(b) Volume: 58.1 ft^3

(c) Power:

(i) Minimum: 285 watts

(ii) Peak: 380 watts

(d) Cost: 13.65 M

b. On-board Research Centrifuge.

The experiments comprising this Functional Program Element would be significantly enhanced by an ability to have an on-board acceleration device capable of imposing constant levels of acceleration between 1 g equivalent and the lowest values practical to provide. Traditionally one thinks of a conventional centrifuge to provide such acceleration fields

although other techniques might prove more desirable in the space station situation.

(1) Research Advantages:

The concept of a "centrifuge" capability offers three major advantages over flying zero g experiments alone. First, the in-flight 1 g control material will experience the launch and recovery acceleration and vibration which cannot be faithfully reproduced on ground based instrumentation. It will also experience the vibration and transient acceleration pulses, during orbit, simultaneously with the zero g experimental package. At the present time these factors must be studied with separate control groups. Even here the control specimens cannot be exposed to representative vibrations in more than one plane simultaneously. Some of the early results of space flight observed on biological material, and attributed to "weightlessnes" have since been identified as resulting from launch and recovery vibration profiles. While some of these factors may be partially clarified by the mid 1970 period, it is certain that many factors will remain unresolved. Thus providing in-flight one g controls will markedly reduce the time and cost of the multiple ground controls now required to interpret the results of space flight experiments. The second advantage is the potential for firmly establishing whether the clinostat often used

in plant research is a valid simulation of the free fall or weightless environment. Some of the results of the Biosatellite experiments are in agreement with those obtained on ground based "null gravity" studies done doing a rotational device in which the resultant gravity vector is zero. Other results do not agree and there is little certainty that "zero g" simulators on the ground faithfully represent the "gravity free" situation of orbital space flight. The third advantage rests in the ability to expose plants and animals to accelerative fields between 0 and 1 g. Thus an early approach to establishing "threshold" responses can be profitably undertaken. We do not know enough about the difference in response to acceleration to define threshold studies. Both phenomena and rough boundaries must be determined in preliminary experiments before in-depth investigations can be begun. The first generation of experiments will not require the sophistication and complexity of one designed for high-density payloads with very precise and complex data acquisition. The required performance characteristics outlined below can be met with a comparatively simple centrifuge that should not impose a heavy demand upon the space station stabilization subsystems. Also the experiments outlined in this FPE, which would be flown on the centrifuge should not impose intolerable time and effort requirements on the crew.

(2) Centrifuge Characteristics:

This considers both D & E type experiments. The maximum figures will accommodate the largest proposed experiment in either group.

(a) Radius: Largest feasible radius is desired; A minimum of 10 ft. would satisfy most all experiments.

(b) Rotation rate: A minimum range of 17 r.p.m. lowered to 1 r.p.m. is required. Based on 10ft. radius this would provide "g" levels from 1 to 3.4×10^{-3} at the outer limit of the arm.

(c) Load Requirements: Minimum equivalent of 1-25 lbs experiment packages per radial arm.

(d) Radial Loading: Assume max. acceleration of 1.5 g with 1025 lbs. package at 10' + 37.5 lbs. per radial arm.

(e) Number of arms. Minimum of 6. If dual counterotating heads, 4 per head to facilitate balancing.

(f) Angular acceleration: No min or max requirements. Should be low but with rapid braking capability for emergency. Rate monitored.

(g) Vibration: Minimal vibration at all speeds. Vibrations at experimental modules to be monitored. Centrifuge need not be isolated from transient acceleration and vibration of spacecraft.

(h) Operating time: Capable of continuous operation up to 300 days. Short interruptions are acceptable to most experiments.

(i) On-Board Data Requirements:

Minimum:

Temperature, humidity, gas pressure, and composition, and verification of satisfactory operation of each package hourly. Vibration and all transient and steady state acceleration and rotation rate continuous with daily data dump.

(j) Special considerations:

(i) Electrical Interfaces.

(aa) Power must be provided for lighting and other environmental controls.

(bb) Data accumulated by slip rings or induction techniques if telemetry is not feasible.

(cc) TV Telemeter link for visual observation of selected experiments.

(dd) EEG telemeter link. EKG etc.

(ii) Mechanical Interfaces.

All experiment packages must be oriented with respect to ground vertical during launch and recovery. Therefore they must be either rotated on centrifuge or attached to the arms in proper orientation after attaining orbit. Early start-up is required. Package attachment must be by simple positive fasteners.

Active cooling required for selected experiments.

Experiment packages currently planned with

individual gaseous environment controls, i.e. 15 psi 80/20 N_2/O_2. Central supply would lighten packages on centrifuge. Requirement applies to launch and recovery as well as to experimental period.

(iii) Accessibility

Centrifuge must be accessible so scientist-astronaut can initiate and service experiments (as required) and remove experimental and/or data packages to prepare from sample return.

(iv) Isolation from cyclic cues resulting from space station activity.

(3) Development Schedule

Phase	A	B	C	D	Flight
FY	70	71	72	73-74	75

(4) Cost

Total $7.0

FY	69	70	71	72	73	74
$ in Thousands	-	200	300	1500	2500	2500

Phase	A	B	C	D
$ in Thousands	200	300	1500	5000

c. Variable packaging geometry can be used.

d. Envelope is undefined.

e. Individual experiment developments are independent of the development of <u>both</u> the space station and Bio E program element.

7. SPECIAL CONSIDERATIONS

a. Minimization of acceleration, vibration and noise in magnitude (or intensity), duration, and frequency of exposure (6 d.f.)* is required.

b. Continuous record of accelerations (6 d.f.) vibrations and noise is required. (See 7 a.)

c. Isolation from all periodic or rhythmic phenomena (vibration, noise, thermal,etc.) is required.

d. On-board centrifuge is desirable (0.1-1.0g) both as an on-board flight control and research tool.

e. Multipurpose photographic capability required for both microscopic and macroscopic objects in both planned and ad hoc research operations.

f. Real-time TV or near-real-time video tape capability desirable for ad hoc observation by ground based P.I. of experiment equipment, procedures, and both microscopic and macroscopic specimens.

g. The animal facility will require an environmental control system isolated from the spacecraft system to permit removal of specimens from their housing for transfer, research procedures or logistics preparation.

h. Scientist-astronaut work space for manipulation of experiments, ancillary equipment and specimens must be provided as a part of the FPE. Capability to pressurize the workspace to sea level

*Footnote: 6 degrees of freedom of acceleration; 3 translational plus 3 rotational.

atmospheric conditions must be provided if on-board scientist is to manipulate specimens in the workspace outside of their containers. Appropriate operational doctrine to permit scientist to do useful work during his decompression periods must be developed.

i. The animal facility will be either internal to the space station or permanently docked.

j. A data handling system common within the Functional Program Element would be desirable to link the experiment sensors through the FPE, through the space station Data Management System to Earth.

k. A common use specimen preservation system would be desirable for freezing or freeze-drying specimens for return to Earth at the usual logistics intervals.

l. Automatic reentry capsules will be desired for return of specimens, photographs, records or total experiment packages.

EXPERIMENT DATA SHEET

THE ROLE OF GRAVITY IN IMMUNE RESPONSES OF MAMMALS

---Effects of weightlessness and/or ionizing radiation upon mobile cells and mucroproteins of interstitial substance in mammals.

---The effect of weightlessness on the immune response of mammals.

1. SPECIFIC OBJECTIVE

a. Determine the effects of weightlessness on the interstitial substance of mammals by detecting physicochemical changes in component mucroproteins and by characterizing morphological and chemical changes in mobile cells of the body.

b. Determine the effect of exposure to weightlessness on the production and persistence of circulating antibodies.

2. GENERAL DESCRIPTION

Studies on the interstitial substance of mammals could be done with any standard laboratory animal. Twenty-four rats from the experiments on growth development and metabolism could be used. Blood samples for examination of the mobile cells would be taken, preserved or fixed in orbit. Evaluation could be done either in orbit by a specialist or on the ground after their return. Selected samples of dissected animals would be made available for analysis of interstitial substance either onboard or after the flight. One continuous experiment would be completed in a 90-day mission.

Studies on the circulatory antibodies of a mammal exposed to weightlessness with radiation are proposed to be done on a convenient sized mammal. The animals would be injected intraperitoneally with a selected

antigen after reaching orbit, and blood withdrawn one week later for the primary response studies. After resting for about three weeks, a second injection would be given and blood withdrawn five days later for the secondary response data. A minimum of 6 animals would be required in each of 2 experiments (in series). If large enough blood samples (about 3-5 ml) can be withdrawn, immunoglobulin species can be determined on recovery. All serologic determinations would be made after recovery, and the animals may then prove useful for future studies of immune responses. In this way, not only relatively short-term data on immune responses could be realized, but also long-term effects, if any, of a fairly long (circa one month) weightless state.

Two complete experiments would be conducted during a 90-day mission.

3. OPERATIONAL CONSTRAINTS

Impact of the total launch and reentry environments upon test specimens must be minimized. Once in orbit, control of the acceleration environment is desirable. Engineering solutions to minimize transient "station connected" g-forces must be achieved. A research centrifuge is desirable. Periodic phenomena, vibration noise, unusual EM fields or other non-terrestrial phenomena should be quantified, recorded, and minimized. Altitude, inclination, and pointing are not critical.

4. MODE OF OPERATION

a. Man attended and manipulated.

b. If attached or integral: isolated from S/C acceleration.
   If detached: dockable for manned access and operations.

c. Continuous operation of basic animal colony equipment with possibly frequent routine adaptation, modification, updating or replacement of equipment for modifications in research plan.

5. CREW SUPPORT

a. Functions:

(1) Laboratory housekeeping, maintenance and repair.

(2) Animal colony management.

(3) Experiment setup.

(4) Monitor animal and equipment condition.

(5) *Ad hoc* research activities. (Desirable to enhance scientific value and responsiveness of experiment, but not critical to successful execution of basic experiment).

(a) Set up follow-on experiments with newly arrived animals.

(b) Common lab techniques, e.g., mass measurement, fluid handling, media preparation.

(c) Gross anatomical examination.

(d) Programmed and *ad hoc* photography.

(e) *Ad hoc* TV monitoring on conference with ground-based P.I.

(f) "Dry" or "moist" chemistry for blood, urine, and other body fluids.

(g) Collect and preserve whole specimens.

(6) Experiment termination.

(7) Specimen preparation for logistics return.

b. Time - for each research activity of the classes below:

(1) Set up - 3 hours.

(2) Housekeeping and colony management - 1/4 hr. per day.

(3) Monitor equipment and animals - 1/4 hr. per day.

(4) Research procedures - up to 4 hrs. per event.

(5) Termination - sacrifice, dissect, preserve, pack for return

c. Duty Cycle: (Requiring up to the suggested time depending on functions finally selected).

(1) Daily routine - 1/2 hr. per day; 365 days.

(2) Ad hoc research procedures.

(a) Interstitial substance studies: 1 experiment; 90 days per experiment.

Set up: 8 hrs. per event; 1 event.

Blood sampling & processing: 1 hr. per even; 1 event per week; 12 weeks.

Termination & packing: 4 hrs. per event; 1 event.

(b) Circulating antibody studies: 2 experiments; 42 days per experiment.

Set up: 4 hrs. per event; 2 events.

Injection: 4 hrs. per event; 4 events.

Blood sampling & processing: 2 hrs. per event; 4 events.

Termination & packing: 4 hrs. per event; 2 events.

d. Skills: Professional physiologist, physician, or gifted technical assistant. See Functions para. 5.a.

e. Special training: Training as research associate with participating P.I.'s.

6. SPACECRAFT SUPPORT

The spacecraft support is assessed against, and included in the support reported in the experiment "The Role of Gravity in Hibernation". Experiment schedules will be arranged to permit serial use of the containers for both experiment activities.

a. Including Experiment Equipment for Centrifuge and 0-g.

(1) Power: N/A

(2) Volume: N/A

(3) Weight: N/A

(4) Envelope: N/A

b. 0-g Experiment Equipment Only:

(1) Power: N/A

(2) Volume: N/A

(3) Weight: N/A

(4) Envelope: N/A

c. Data

(1) Continuous; dump each orbit:

(a) Accelerations in 6 d.f.; magnitude duration and frequency

(b) Vibration in 6 d.f.: amplitude, frequency and duration

(c) Noise, frequency, intensity and duration

(d) Ambient radiation level.

(2) Hourly record; dump daily:

(a) Ambient temperature in containers

(b) Relative humidity

(c) Gas composition and pressures; Total pressure plus partial pressures of up to 10 gases, e.g., O_2, N_2, CO_2, CO, etc.

(d) Illumination verification: on/off, periodicity, intensity

(e) Rate of rotation of centrifuge

(3) Dependent on design of experiment:

(a) Event actuation/termination, verification

(b) Monitoring or critical experiment measurements, for example, below:

heart rate
ECG
Blood pressure
cardiac output
O_2 content of blood
CO_2 content of blood
Respiration rate
O_2 consumption
CO_2 output
Body temperature
Thermal output
Body fluids composition (blood, urine, etc.)
Automated Manual with tape recording of data
EEG
EMG
Animal activity

(c) Photographic film processing and storage

(d) Radiation intensity data from planned experiments

(e) Specimen logistics return

(f) Photograph logistics return.

(4) Ad hoc - only occasional:

(a) Photograph transmission by RF.

(b) Real-time or near-real-time TV

(c) Emergency radiation intensity data.

7. DEVELOPMENT SCHEDULE

Phase	A	B	C	D	Flight
FY	69	70	71	72-73	75

8. COST

Total: $1.8 M (excluding centrifuge).

FY	69	70	71	72	73	74	75
$ in Thousands	100	200	400	400	600	50	50
Phase	A	B	C	D	Data Reduction		
$ in Thousands	100	200	400	1050	50		

EXPERIMENT DATA SHEET

THE ROLE OF GRAVITY IN THE FUNCTION OF THE MAMMALIAN ORGANISM THROUGH ITS LIFE CYCLE

---Pregnancy and oestrous cycle in the orbiting rat.

---Differentiation and development in mammals conceived under conditions of zero-gravity.

---Growth and behavior of individuals born in space and of those born on the Earth.

---Effects of weightlessness on the development of the vestibular apparatus in mice.

---The effects of weightlessness on central nervous system development.

---The effect of weightlessness upon food intake regulation in normal and mutant mice.

---Turnover of mineralized tissues.

---Metabolic adaptation to prolonged space flight.

---Utilization of depressed metabolism in mammals during space flight.

---Exercise as a countermeasure to muscle and bone atrophy in space.

---Effect of weightlessness on the accumulation of aging pigment in nerve cells and heart muscle of rats.

2. GENERAL DESCRIPTION

The grouping of these research activities into a single entity was based on two major factors. The first is the need for multiple use of animals by P.I.'s cooperating despite their differing information needs. Prohibitive numbers of test animals would otherwise be required. The

second factor was the possibility of providing a single animal 0-g facility with many standard subunits. Special accessories employed as needed by the onboard scientist would adapt the standard housing unit for breeding, metabolic studies, isolation, behavioral measures, restraint, exercise, radiation exposure, etc.

Another major feature of the standard units would be their useability on the research centrifuge required to provide onboard 1-g controls or fractional g experiments. The centrifuge provides a new level of sophistication in biological research in space and must be considered potentially applicable to all experiments cited below although not specifically referenced.

A number of research approaches may be described for several characteristic periods of the life cycle.*

Prenatal Stage: The body functions of the female will be significant in estrus, conception, pregnancy, parturition, lactation and resumption of estrus. Changes in vaginal epithelium will be followed through the estrus cycle. During the following pregnancy, a battery of data such as EKG, EEG, metabolic measures, biochemistry of blood and urine, behavior, etc., will be recorded to give a continuous report on the female's response to the abnormal environment.

In parallel the same vital functions of the embryo, fetus or new born animal will be monitored as early as they become detectable. Intra uterine photos will enable the researcher to detect anomalies early and

*Footnote: Note that indepth study of the cardiovascular system has been set up as an independent experiment because of its unique importance.

follow them to term. The newborn animals will receive intensive examinations for gross anatomical, physiological, and biochemical anomalies. Throughout the pregnancy, females and young will be sacrificed to provide specimens for in-depth anatomical, histological and biochemical study both on board and after return to Earth. Living and preserved specimens will be returned routinely.

Juvenile Stage: Through this period of major growth and development the progress of the individual and of specific organ systems of interest will be followed. The battery of anatomical, physiological and biochemical measurements will be continued and expanded as required. Increased emphasis will be placed on the behavioral measures in order to see the evolution of sensorimotor coordination and the higher CNS functions such as learning in the abnormal environment.

Puberty: At this critical period of development special attention will be focused on the emergence of both primary and secondary physical, physiological, and behavioral characteristics.

Maturity: The animals born in weightlessness will be followed as long as the mission permits. However, in order to study some aspects of maturity, special strains or different rodent species may be used. In addition to the battery of tests already described, special studies will be initiated on food intake vs. g level; in-depth metabolism of especially interesting tissues such as bone and muscle (as a consequence of data derived from animals bred in 0-g); intermediary metabolism using isotope tracers, providing sensitive advance indicators of impending physiological changes before their advent.

Senescence: Other specimens in their late maturity will be introduced to permit a thorough anatomical, physiological, and behavioral investigation of the processes of senescence and natural death as modified by the weightless environment.

Finally, a "zero-g line" of animals should be established. A second generation and possibly a third could be reared in the planned mission duration. This would not only have the obvious genetic implications, but would also provide the opportunity for really long-term accumulative, non-genetic, malfunctions to emerge for detailed study in space and on Earth.

Throughout the whole post-natal period, living and dead animals plus accumulated specimens will be periodically returned to Earth.

3. OPERATIONAL CONSTRAINTS

Impact of the total launch and reentry environments upon test specimens must be minimized. Once in orbit, control of the acceleration environment is desirable. Engineering solutions to minimize transient "station connected" g-forces must be achieved. A research centrifuge must be provided. Periodic phenomena vibration, noise, unusual EM fields, or other non-terrestrial phenomena should be quantified, recorded, and minimized. Altitude, inclination, and pointing are not critical.

4. MODE OF OPERATION

a. Man attended and manipulated.

b. If attached or integral: isolated from S/C accelration.

If detached: dockable for manned access and operations.

c. Continuous operation of basic animal colony equipment with possibly frequent routine adaptation, modification, updating, or replacement of equipment for modifications in research plan.

5. CREW SUPPORT

a. Functions:

(1) Laboratory housekeeping, maintenance and repair.

(2) Animal colony management.

(3) Experiment setup.

(4) Monitor animal and equipment condition.

(5) *Ad hoc* research activities. (Desirable to enhance scientific value and responsiveness of experiment, but not critical to successful execution of basic experiment).

(a) Modify experiment as progeny delivered.

(b) Set up follow-on experiments with:

(i) progeny

(ii) onboard adults

(iii) newly arrived animals

(c) Common lab techniques, e.g., mass measurement, photography, fluid handling, media preparation.

(d) Gross anatomical examination.

(e) Programmed and *ad hoc* photography.

(f) *Ad hoc* TV monitoring in conference with ground based P.I.

(g) Install and operate EKG, EEG, EMG, physiological and metabolic instrumentation, etc.

(h) "Dry" or "moist" chemistry for blood, urine, and other body fluids.

(i) Behavioral and CNS test battery.

(j) Prepare, fix, stain smears.

(k) Collect bacteriological samples, inoculate and culture for presumptive tests.

(l) Radiobiology techniques

(i) Irradiation

(ii) Isotopic tracers - administer and detect.

(m) Collect and preserve whole specimens.

(n) Dissect and preserve specimens.

(o) Isolate, fix, section, stain tissues.

(6) Experiment termination.

(7) Specimen preparation for logistics return.

b. Time - For each major research activity of the classes below:

(1) Setup - 8 hours.

(2) Housekeeping and colony management - 1/2 hr per day.

(3) Monitor equipment and animals - 1/2 hr per day.

(4) Research procedures - up to 2 hrs per event.

(5) Termination - sacrifice, dissect, preserve, pack for return - 16 hours.

c. Duty Cycle: (Requiring up to the suggested time depending on functions finally selected).

(1) Assumptions:

(a) 20 Experiments in series-parallel.

(b) Duration varies from 1 week to 12 weeks (senescence).

(c) The animal housing units are continually occupied through appropriate scheduling for the 1-year lifetime of the Bio D program.

(2) Setup: 8 hrs. per event; 20 events.

(3) Daily routine: 1 hr. per day; 365 days.

(4) Ad hoc research procedures: 2 hrs. per event; 5 events per week; 52 weeks.

(5) Termination and packing 8 hrs. per event; 20 events.

d. Skills: Professional physiologist or gifted technical assistant. See "Functions", para. 5.a.

e. Special training: Training as research associate with participating P.I.s.

6. SPACECRAFT SUPPORT

Includes the requirements for the following additional experiments:

---The Role of Gravity in Cardiovascular Function.

---The Influence of Gravity on Behavior in Mammals.

a. Including Experiment Equipment for Centrifuge and 0-g.
Excludes weight of centrifuge itself.
Based on estimated 64 containers at 0-g and 64 containers at various acceleration levels up to 1-g. Total 128 units.

(1) Power:

(a) Average: 400 watts

(b) Peak: 500 watts

(2) Volume:

(a) Specimens, housing and expendables: 69 ft^3

(b) Ancillary research equipment: 4.0 ft^3

(3) Weight:

(a) Specimens, housing and expendables: 500 lbs.

(b) Ancillary research equipment: 100 lbs.

(4) Envelope: (0-G only: Centrifuge units variable geometry).

(a) Specimens, housing and expendables: 3 units, each 6½ ft x 3½ ft x ½ ft.

(b) Ancillary research equipment: To be determined - not critical.

b. 0-g experiment equipment only:

Based on estimated 64 animal containers at 0-g only, in near-continuous use:

(1) Power:

(a) Average: 200 watts

(b) Peak: 250 watts

(2) Volume:

(a) Specimens, housing and expendables: 34.5 ft^3

(b) Ancillary research equipment: 2.0 ft^3

(3) Weight:

(a) Specimens, housing and expendables: 250 lbs.

(b) Ancillary research equipment: 50 lbs.

(4) Envelope:

(a) Specimens, housing and expendables: 3 units each 6½ ft x 3½ ft x ½ ft.

(b) Ancillary Research Equipment: To be determined - not critical.

e. Data

(1) Continuous; dump each orbit:

(a) Accelerations in 6 d.f.; magnitude duration and frequency

(b) Vibration in 6 d.f.: amplitude, frequency and duration

(c) Noise, frequency, intensity and duration

(d) Ambient radiation level

(2) Hourly record; dump daily:

(a) Ambient temperature in containers

(b) Relative humidity

(c) Gas composition and pressures: Total pressure plus partial pressures of up to 10 gases, e.g., O_2, N_2, CO_2, CO, etc.

(d) Illumination verification: on/off, periodicity, intensity

(e) Rate of rotation of centrifuge

(3) Dependent on design of experiment:

(a) Event actuation/termination, verification

(b) Monitoring or critical experiment measurements, for example, below:

heart rate
ECG
Blood pressure
cardiac output
O_2 content of blood
CO_2 content of blood
Respiration rate
O_2 consumption
CO_2 output
body temperature
thermal output
body fluids composition (blood, urine, etc.)
Automated Manual with tape recording of data
EEG
EMG
animal activity

(c) Photographic film processing and storage

(d) Radiation intensity data from planned experiments

(e) Automatic data and specimen reentry capsule

1 - 2 per experiment.

(f) Specimen logistics return

(g) Photograph logistics return.

(4) Ad hoc - only occasional:

(a) Photograph transmission by RF.

(b) Real time or near-real time TV.

(c) Emergency radiation intensity data.

7. DEVELOPMENT SCHEDULE

Phase	A	B	C	D	Flight
FY	69-70	70-71	71-72	73-74	75

8. COST

Total: 3.8 M (excluding centrifuge).

FY	69	70	71	72	73	74	75
$ in Thousand	100	400	500	500	1000	1000	300

Phase	A	B	C	D	Data Reduction
$ in Thousand	200	400	900	2000	300

EXPERIMENT DATA SHEET

THE ROLE OF GRAVITY IN HIBERNATION

---Central Nervous System Function in Hibernating or Hypothermic Marmots at Zero Gravity

1. SPECIFIC OBJECTIVE

Provide answers to the following questions:

(1) Will an animal remain in or return to hibernation upon exposure to weightlessness?

(2) Are the modes of information handling by the central nervous system during hibernation, hypothermia and normothermia altered by the space environment?

2. GENERAL DESCRIPTION

Animals flown to Earth orbit during their winter hibernation period will be monitored for signs of breaking their dormant state and if so their reentry of this state after several weeks of exposure to weightlessness.

Studies of information handling by the central nervous system would be carried out by observing and interpreting spontaneous cortical and subcortical potentials as well as evoked potentials and behavioral responses to specific stimuli.

Associated measurements for correlation with CNS/hibernation studies (as well as independent interpretation) would include renal, ionic and metabolic balance studies, cardiovascular system responses gradient calorimetry and biorhythms over long term exposure to weightlessness.

Onboard comparison studies of hypothermic animals, induced by chemical means, and normothermic animals in a sleep-like state produced by low frequency stimulation of the reticular formation should aid interpretation of the basic hibernation/weightlessness studies.

3. OPERATIONAL CONSTRAINTS

Impact of the total launch and reentry environments upon test specimens must be minimized. Once in orbit, control of the acceleration environment is highly desirable. Engineering solutions to minimize transient "station connected" g-forces must be achieved. A research centrifuge must be desirable. Periodical phenomena, vibration, noise, and unusual EM fields and other non-terrestrial phenomena must be quantified, recorded, and minimized. Altitude, inclination, and pointing are not critical.

4. MEANS OF OPERATION

a. Man attended and manipulated.

b. If attached or integral: isolated from S/C acceleration.

If detached: dockable for manned access and operations.

c. Continuous operation of basic animal colony equipment with possible routine adaptation, modification, updating or replacement of equipment for modifications in research plan.

5. CREW SUPPORT

a. Functions:

(1) Laboratory housekeeping, maintenance, and repair.

(2) Animal colony management.

(3) Experiment setup.

(4) Monitor animal and equipment condition.

(5) Ad hoc research activities (Desirable to enhance scientific value and responsiveness of experiment, but not critical to successful execution of basic experiment.)

(a) Set-up follow-on experiments with:

(i) onboard adults

(ii) newly arrived animals

(b) Common lab techniques, e.g., mass measurement, photography, fluid handling, media preparation.

(c) Gross anatomical examination.

(d) Programmed and ad hoc photography.

(e) Ad hoc TV monitoring in conference with groundbased P.I.

(f) Install and operate EKG, EEG, physiological, and metabolic instrumentation, etc.

(g) "Dry" or "moist" chemistry for blood, urine, and other body fluids.

(h) Behavioral and CNS test battery.

(i) Prepare, fix, stain smears.

(j) Collect and preserve whole specimens.

(k) Dissect and preserve specimens.

(6) Experiment termination.

(7) Specimen preparation for logistics return.

b. Time - for each major research activity of the classes below:

(1) Set-up: 8 hrs.

(2) Housekeeping: 1/4 hr. per day.

(3) Monitor equipment and animals: 1/4 hr. per day.

(4) Research procedures: up to 2 hrs. per event.

(5) Termination, pack for return: 8 hrs.

c. Duty Cycle: (Requiring up to the suggested time depending on functions finally selected.)

(1) Assumptions:

(a) Six experimental animals: 2 hibernating or 2 in hypothermia, plus 2 in normothermia as 0-g controls plus 2 as onboard 1 g controls.

(b) Run simultaneously.

(c) Duration: 25 weeks.

(2) Set-up: 1 hr. per event; 4 events.

(3) Daily routine: 1 hr. per day; 175 days.

(4) *Ad hoc* research procedures: 2 hrs. per event; average of 1 event per week; 25 weeks.

(5) Termination and packing: 8 hrs. per event; 2 events.

d. Skills: Professional physiologist or gifted technical assistant. See "Functions," para. 5.a.

e. Special Training: Training as research associate with participating P.I.'s.

6. SPACECRAFT SUPPORT

Includes the requirements for the experiment: "The Role of Gravity in Immune Responses of Mammals."

a. Including Experiment Equipment for Centrifuge and 0-g: Excludes

weight, etc., of centrifuge. Based on 2 animals (units) in hibernation (or hypothermia) at 0-g, 2 animals at normothermia in 0-g, and 2 animals in hypothermia in 1.0 g. Total of 6 units (animals).

(1) Power: Continuous 30 watts.

(2) Volume:

(a) Specimens, housing and expendables: 18 ft^3 (3 ft^3 per unit)

(b) Ancillary research equipment: 0.5 ft^3

(3) Weight:

(a) Specimens, housing and expendables: 180 lbs. (30 lbs. per unit)

(b) Ancillary research equipment: 10 lbs.

(4) Envelope:

(a) Specimens, housing and expendables: 6 units, each 1 1/2 x 1 x 2 ft.

(b) Ancillary research equipment: To be determined - not critical.

b. 0-g Experiment Equipment Only

Based on 2 animals (units) in hibernation or hypothermia in 0-g plus 2 animals in normothermia in 0-g. Total of 4 units (animals).

(1) Power: Continuous 30 watts

(2) Volume:

(a) Specimens, housing and expendables: 12 ft^3 (3 ft^3 per unit)

(b) Ancillary research equipment: 0.5 ft^3

(3) Weight:

(a) Specimens, housing and expendables: 120 lbs. (80 lbs per unit)

(b) Ancillary research equipment: 10 lbs.

(4) Envelope:

(a) Specimens, housing and expendables: 4 units, each 1 1/2 x 1 x 2 ft.

(b) Ancillary research equipment: To be determined - not critical.

c. Data

(1) Continuous; dump each orbit:

(a) Accelerations in 6 d.f.: magnitude duration and frequency.

(b) Vibration in 6 d.f.: amplitude, frequency and duration.

(c) Noise, frequency, intensity and duration.

(d) Ambient radiation level.

(2) Hourly record; dump daily:

(a) Ambient temperature in containers.

(b) Relative humidity.

(c) Gas composition and pressures: Total pressure plus partial pressures of up to 10 gases, e.g., O_2, N_2, CO_2, CO, etc.

(d) Illumination verification: on/off, periodicity, intensity.

(e) Rate of rotation of centrifuge.

(3) Dependent on design of experiment:

(a) Event actuation/termination, verification.

(b) Monitoring or critical experiment measurements, for example, below:

Heart rate

ECG

Blood pressure

Cardia output

O_2 content of blood

CO_2 content of blood

O_2 consumption

CO_2 output

Body temperature

Thermal output

Body fluids composition (blood, urine, etc.)

Automatic Manual with tape recording of data

EEG

EMG

Animal activity

(c) Photographic film processing and storage

(d) Specimen logistics return

(e) Photograph logistics return

(b) Ad hoc - only occasional:

(a) Photograph transmission by RF.

(b) Real-time or near-real time TV.

7. DEVELOPMENT SCHEDULE

Phase	A	B	C	D	Flight
FY	70	71	72	73-74	75

8. COST

Total $0.95M

FY	69	70	71	72	73	74	75
$ in thousands	--	100	200	200	200	200	50

Phase	A	B	C	D	Data Reduction
$ in thousands	100	200	200	400	50

EXPERIMENT DATA SHEET

THE INFLUENCE OF GEOPHYSICAL FACTORS ON BIORHYTHMS IN VERTEBRATES

---Effects of the Earth Orbital Environment on Biorhythms in Rats - Halbert & Pitts

---Effect of Gravity on Biorhythms of Animals - Lafferty

1. SPECIFIC OBJECTIVE

To determine whether selected biorhythms in mammals are due to "built-in" biological clocks or are due to geophysical and selenophysical influences which cue the regulation of these phenomena.

2. GENERAL DESCRIPTION

Numerous studies of biorhythms have been carried out on Earth, including various geographical shift experiments. The biorhythms of certain rats and mice are well established in the normal Earth environment. It is planned the Biopioneer flights will give data on the persistence of these rhythms, when the animals are in heliocentric orbit far from terrestrial or lunar influences.

Useful comparisons can be drawn by placing these animals in long-term Earth orbit; the periodicity of any geophysical or selenophysical factors may be significantly changed. A single species would be chosen by both P.I.'s, probably the mouse.

For example, eight replicate groups of 4-month old male rats will be studied in terms of gross motor activity, rectal temperature, heart and ventilation rates, and, if possible, steroid excretion in urine. Each group in its capsule of ten pounds will be composed of four rats; total -

16 rats. By maintenance in alternating light and darkness for three weeks, the time relations on a 24-hour schedule among these rhythms under extra-terrestrial conditions will be mapped for one group. The mice will then be subjected to a 180° phase shift in light-dark cycle and studied for the ensuing two weeks. Next the mice will be retrained to the original 24 hour light-dark cycle. Following retraining, they will be subjected to constant darkness for a period sufficient to investigate their "free running" functions. After retraining to the original 24 hour light-dark cycle the mice will be exposed to alternating 4-hour periods of light and dark.

During these experiment periods periodograms, variance spectra and cross-spectra of these functions on these regimens will reveal any changes in the behavior of different components encountered in outer space as compared to those obtained for simultaneous ground controls.

Repetitions of these experiments, alterations of programming for the identical animals, or introduction of new animals for follow-on experiments can be expedited by use of reusable/adaptable animal cages.

3. OPERATIONAL CONSTRAINTS

Impact of the total launch and reentry environments upon test specimens must be minimized. Once in orbit control of the acceleration environment is critical. Engineering solutions to minimize transient "station connected" g-forces must be achieved. The animals must be isolated from any periodical phenomena and from noise, vibration, unusual EM fields or other non-terrestrial phenomena. Altitude, inclination, and pointing are not critical. A centrifuge is not desired.

4. MODE OF OPERATION

a. Man attended and manipulated.

b. If attached or integral: isolated from S/C acceleration.

If detached: dockable for manned access and operations.

c. Continuous operation of basic animal colony equipment with frequent routine adaptation, modification, updating or replacement of equipment for modifications in research plan may be required.

5. CREW SUPPORT

a. Functions:

(1) Laboratory housekeeping,maintenance, and repair.

(2) Animal colony management.

(3) Experiment setup.

(4) Monitor experiment status.

(5) Alter light-dark cycle in accord with research protocol.

(6) Ad hoc research activities. (Desirable to enhance scientific value and responsiveness of experiment, but not critical to successful execution of basic experiment.)

(a) Setup follow-on experiments with:

(i) progeny of space-bred adults

(ii) onboard adults

(iii) newly arrived animals

(b) Common lab techniques, e.g., mass measurement, photography, fluid handling, media preparation.

(c) Gross anatomical examination.

(d) Programmed and ad hoc photography.

(e) Ad hoc TV monitoring in conference with groundbased P.I.

(f) Install and operate EKG, EEG, physiological and metabolic instrumentation, etc.

(g) "Dry" or "moist" chemistry for blood, urine, and other body fluids.

(h) Behavior and CNS test battery.

(7) Experiment termination.

(8) Specimen preparation for logistics return.

b. Time - For each major research activity of the classes below:

(1) Setup - 8 hours.

(2) Housekeeping and colony management: 1/4 hr per day.

(3) Monitor equipment and animals: 1/4 hr per day.

(4) Research procedures: 1 hr per day.

(5) Termination - pack for return 8 hours.

c. Duty Cycle: (Requiring up to the suggested time depending on functions finally selected.)

(1) Assumptions:

(a) one basic experiment; four simultaneous replicates.

(b) Duration: 13 weeks minimum.

(c) Follow-on experiments not defined.

(2) Setup: Eight hours per event; one event.

(3) Daily routine: 1/2 hr per day; minimum 91 days.

(4) Ad hoc research procedures: 1 hr per event; minimum 5 events.

(5) Termination and packing: 8 hrs per event; 1 event.

d. Skills: Professional physiologist or gifted technical assistant. See "Functions," para. 5.a.

e. Special Training: Training as research associate with participating P.I.'s.

6. SPACECRAFT SUPPORT

The centrifuge is not employed in this experiment. Based on estimated four units of four rats each in 0-g only. Therefore, both cases below are identical.

a. Including Experiment Equipment for centrifuge and 0-g:

(1) Power:

(a) Average: 25 watts

(b) Peak: 75 watts

(2) Volume:

(a) Specimens, housing and expendables: 6 ft^3 ($1\ 1/2\ ft^3$ per unit)

(b) Ancillary research equipment: 0.5 ft^3

(3) Weight:

(a) Specimens, housing and expendables: 40 lbs. (10 lbs per unit)

(b) Ancillary research equipment: 10 lbs.

(4) Envelope:

(a) Specimens, housing and expendables: 3 x 2 x 1 ft.

(b) Ancillary research equipment: To be determined - not critical.

b. 0-g Experiment Equipment Only:

(1) Power:

(a) Average: 25 watts

(b) Peak: 75 watts

(2) Volume:

(a) Specimens, housing and expendables: 6 ft^3

(b) Ancillary research equipment: 0.5 ft^3

(3) Weight:

(a) Specimens, housing and expendables: 40 lbs.

(b) Ancillary research equipment: 10 lbs.

(4) Envelope:

(a) Specimens, housing and expendables: 3 x 2 x 1 ft.

(b) Ancillary research and equipment: To be determined - not critical.

c. Data:

(1) Continuous; dump each orbit:

(a) Activity

(b) Body temperature

(c) Heart rate

(d) Respiratory rate

(e) Accelerations in 6 d.f.: magnitude duration and frequency

(f) Vibration in 6 d.f.: amplitude, frequency and duration

(g) Noise, frequency, intensity and duration.

(h) Ambient radiation level

(2) Hourly record; dump daily:

(a) Ambient temperature in containers

(b) Relative humidity

(c) Gas composition and pressures: Total pressure

plus partial pressures of up to 10 gases, e.g., O_2, N_2, CO_2, CO, etc.

(d) Illumination verification: on/off, periodicity, intensity

(e) Rate of rotation of centrifuge

(3) Dependent on design of experiment:

(a) Event actuation/termination, verification

(b) Urine collection and storage or analysis

(c) Photographic film processing and storage

(d) Specimen logistics return

(e) Photograph logistics return

(4) Ad hoc - only occasional

(a) Photograph transmission by RF

(b) Real time or near-real time TV

7. DEVELOPMENT SCHEDULE

Phase	A	B	C	D	Flight
FY	69-70	70-71	72	73-74	75

8. COST

Total: $1.55M

FY	69	70	71	72	73	74	75
$in thousands	25	100	155	400	400	400	50

Phase	A	B	C	D	Data Reduction
$in thousands	100	200	400	800	50

EXPERIMENT DATA SHEET

THE INFLUENCE OF GRAVITY ON BEHAVIOR IN MAMMALS

---Orbiting Behavioral Centrifuge

1. SPECIFIC OBJECTIVE

(1) To determine the rat's ability to detect acceleration and discriminate intensity.

(2) To determine g-levels preferred by rats from various backgrounds.

2. GENERAL DESCRIPTION

Rats of differing histories (e.g., born on ground vs. born in space; various stages of development) will be used for these experiments. The space-born animals used will be drawn from those used for life cycle and physiology studies described elsewhere. Precautions will be taken to assure that interactions between experiment conditions will not occur to confound the experiments.

The behavior of trained rats provides a highly sensitive indicator in disorientation tests. Such rats will be exposed to acceleration in a research centrifuge at different g-levels as a function of radius and rate of rotation. Behavior during choice, ability to discriminate small differences, and final choice will be observed. The rats will be monitored to identify physiological correlates with specific behavioral incidents.

3. OPERATIONAL CONSTRAINTS

Impact of the total launch and reentry environments upon the test specimens must be minimized. Once in orbit, control of the acceleration

environment is desirable. Engineering solutions to minimize transient "station connected" g-forces must be achieved. A research centrifuge must be provided. Periodic phenomena, vibration, noise, unusual EM fields or other non-terrestrial phenomena must be quantified, minimized and recorded. Altitude, inclination, and pointing are not critical.

4. MODE OF OPERATION

a. Man attended and manipulated.

b. If attached or integral: isolated from S/C acceleration. If detached: dockable for manned access and operations.

c. Continuous operation of basic animal colony equipment with possibly frequent routine adaptation, modification, updating or replacement of equipment for modifications in research plan.

5. CREW SUPPORT

a. Functions:

(1) Laboratory housekeeping, maintenance, and repair.

(2) Animal colony management.

(3) Experiment set-up.

(4) Monitor animal and equipment condition.

(5) Ad hoc research activities. (Desirable to enhance scientific value and responsiveness of experiment, but not critical to successful execution of basic experiment).

(a) Setup follow-on experiments with:

(i) progeny of embryology studies.

(ii) onboard adults.

(iii) Newly arrived animals.

(b) Common lab techniques, e.g., mass measurement, photography, fluid handling, media preparation.

(c) Gross anatomical examination.

(d) Programmed and ad hoc photography.

(e) Ad hoc TV monitoring in conference with ground based P.I.

(f) Install and operate EKG, EEG, physiological and metabolic instrumentation, etc.

(g) Behavioral and CNS test battery.

(6) Experiment termination.

(7) Specimen preparation for logistics return.

b. Time - For each major research activity of the classes below:

(1) Set-up - 8 hrs.

(2) Housekeeping and colony management - 1/4 hr. per day.

(3) Monitor equipment and animals - 1/4 hr/day.

(4) Research procedures - up to 2 hrs. per event.

(5) Termination - 4 hrs. per event.

c. Duty Cycle: (Requiring up to the suggested time depending on functions finally selected.)

(1) Assumptions:

(a) 1 Experiment period.

(b) Earth-born and space-born animals will be used simultaneously.

(c) Duration: 8 weeks per experiment.

(2) Set-up: 8 hrs. per event; 2 events.

(3) Daily routine: 1/2 hr. per day: 56 days.

(4) _Ad hoc_ research procedures: up to 2 hrs per event; 1 event per day; 7 days per test period; 4 test periods.

(5) Termination and packing: 4 hrs. per event; 1 event.

d. Skills: Professional behavioral psychologist, physiologist or gifted technical assistant. See "Functions", para. 5.a.

e. Special Training: Training as research associate with participating P.I.'s.

6. SPACECRAFT SUPPORT

The spacecraft support required is assessed against, and included in, the support reported in the experiment "Role of Gravity in the Function of the Mammalian Organism Throughout its Life Cycle".

a. Including Experiment Equipment for Centrifuge and 0-g.

(1) Power: N/A

(2) Volume: N/A

(3) Weight: N/A

(4) Envelope: N/A

b. 0-g Experiment Equipment Only.

(1) Power: N/A

(2) Volume: N/A

(3) Weight: N/A

(4) Envelope: N/A

c. Data

(1) Continuous; dump each orbit:

(a) Accelerations in 6 d.f.: magnitude duration and frequency

(c) Noise, frequency, intensity and duration

(d) Ambient radiation level.

(2) Hourly record; dump daily:

(a) Ambient temperature in containers

(b) Relative humidity

(c) Gas composition and pressures: Total pressure plus partial pressures of up to 10 gases, e.g., O_2, N_2, CO_2, CO, etc.

(d) Rate of rotation of centrifuge

(3) Dependent on design of experiment:

(a) Event actuation/termination, verification

(b) Monitoring or critical experiment measurements, for example, below:

Various Behavioral Measures
heart rate
O_2 consumption
CO_2 output
Body temperature
EEG
EMG
animal activity

(c) Photographic film processing and storage

(d) Automatic data and specimen reentry capsule 1 - 2 per experiment.

(e) Specimen logistics return

(f) Photograph logistics return.

(4) Ad hoc - only occasional:

7. DEVELOPMENT SCHEDULE

Phase	A	B	C	D	Flight
FY	68	69-70	71-72	73-74	75

8. COST

Total: $1.025 M (excluding centrifuge)

FY	69	70	71	72	73	74	75
$ in Thousands	25	125	150	150	300	250	25

Phase	A	B	C	D	Data Reduction
$ in Thousands	--	150	300	550	25

EXPERIMENT DATA SHEET

THE ROLE OF GRAVITY IN CARDIOVASCULAR FUNCTION*

---Circulatory Adaptation During Long-Term Weightlessness

1. SPECIFIC OBJECTIVES

To determine the nature, time course, and final extent of cardiovascular changes in rats exposed to conditions of space flight over long periods of time. The physical stresses affecting an astronaut in a space vehicle during the reentry will be the same after a short or long-term period of weightlessness. However, it is likely that physiologically these stresses will be tolerated quite differently. While the increased G-forces during landing are tolerated well after a short space flight, it is likely that after a long-term weightlessness the astronaut's ability to tolerate the increased G-forces will be decreased because of adaptive changes of his cardiovascular system.

2. GENERAL DESCRIPTION

Ten white adult rats will be used in 0-g for this experiment; ten rats at each of two levels of acceleration will also be used as onboard centrifuge controls. The polyethylene tubings will be surgically implanted in the aorta and right ventricle of all animals prior to the experiment. After 3-4 days when the animals recover from the perative procedures they will undergo a series of cardiovascular studies in our laboratory. These studies

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* The cardiovascular area has been set up as a separate research area because of its unique importance.

will include measurements of the heart rete and intraventricular EKG, ventricular and aortic blood pressure, oxygen content of arterial and venous blood, and cardiac output. Furthermore, oxygen consumption, deep body temperature and electromyograms from a group of back muscles will also be recorded. During this part of the experimental information will be obtained on unrestrained, unanesthetized animals. These investigations will last 2-4 weeks. Animals will then be placed into specially constructed "walking chambers" where they will be semi-restrained and the same data collected during a period of 1-2 weeks. This period will be sufficient for experimental animals to adapt to the new situation. The third step of the experiment will be to expose the animals during a space flight to effects of weightlessness lasting 6-8 weeks. The same physiological data as in earlier parts of the experiment will be monitored and recorded by a tape recorder. The data might also be telemetered to the Earth. The monitoring of physiological data will continue during the reentry and the recovery of the rats. During the last part of the experiment the same measurements will be made. This part of the experiment will last several months or maybe even two to three years, i.e., as long as the animals live. It is possible to extend the experiments so long because the cannulation technique we developed in 1960 has been so much improved that now the patency of cannulas is well over 150 days and in many animals the cannulas last until the animals die of old age.

3. OPERATIONAL CONSTRAINTS

Impact of the total launch and reentry environments upon test specimens must be minimized. Once in orbit, control of the acceleration

environment is desirable. Engineering solutions to minimize transient "station connected" g-forces must be achieved. A research centrifuge must be provided. Periodical phenomena, vibration and noise, unusual EM fields or other non-terrestrial phenomena should be quantified, recorded and minimized. Altitude, inclination and pointing are not critical.

4. MODE OF OPERATION

a. Man attended and manipulated.

b. If attached or integral: isolated from S/C acceleration.
   If detached: dockable for manned access and operations.

c. Continuous operation of basic animal colony equipment possibly with frequent routine adaptation, modification, updating, or replacement of equipment for modifications in research plan.

5. CREW SUPPORT

a. Functions:

(1) Laboratory housekeeping, maintenance and repair.

(2) Animal colony management.

(3) Experiment setup.

(4) Monitor animal and equipment condition.

(5) *Ad hoc* research activities. (Desirable to enhance scientific value and responsiveness of experiment but not critical to successful execution of basic experiment.)

(a) Setup follow-on experiments with:

(i) onboard adults

(ii) newly arrived animals

(iii) progeny from experiment in embryogenesis

(b) Common lab techniques, e.g., mass measurement, fluid handling, spectrographic determinations.

(c) Gross anatomical examination.

(d) Programmed and ad hoc photography.

(e) Ad hoc TV monitoring in conference with ground based P.I.

(f) Operate EKG, EMG, physiological and metabolic instrumentation, etc. Assemble such equipment.

(g) "Dry" or "moist" chemistry for blood, urine, other body fluids.

(h) Prepare, fix and stain smears.

(i) Collect and preserve whole specimens.

(j) Radiobiology techniques - Isotopic tracers - administer and detect.

(6) Experiment termination.

(7) Specimen preparation for logistics return.

b. Time - For each major research activity of the classes below:

(1) Setup - 8 hours.

(2) Housekeeping and colony management - 1/4 hr/day.

(3) Monitor equipment and animals - 1/4 hr/day.

(4) Research procedures - up to 2 hours per event.

(5) Termination - sacrifice, preserve, pack for return - 8 hours.

c. Duty Cycle: (Requiring up to the suggested time depending on functions finally selected).

(1) Assumptions:

(a) 1 experiment

(b) Duration - 60 days.

(2) Setup: 8 hrs/event; 1 event.

(3) Daily routine: 1/2 hr/day; 60 days.

(4) Ad hoc research activities: 2 hrs. per event; 2 events per week; 9 weeks.

(5) Termination and packing: 8 hrs per event; 1 event.

d. Skills: Ph.D. physiologist, M.D., or gifted technical assistant. See "Functions," para. 5.a.

e. Special Training: Training as research associate with participating P.I.'s.

6. SPACECRAFT SUPPORT

The spacecraft support required is assessed against, and included in, the support reported in the experiment "Role of Gravity in the Function of the Mammalian Organism Throughout its Life Cycle."

a. Including Experiment Equipment for Centrifuge and 0-g:

(1) Power: N/A (Not Applicable).

(2) Volume: N/A

(3) Weight: N/A

(4) Envelope: N/A

b. 0-g Experiment Equipment Only:

(1) Power: N/A

(2) Volume: N/A

(3) Weight: N/A

(4) Envelope: N/A

c. Data

(1) Continuous; dump each orbit:

(a) Accelerations in 6 d.f.; magnitude duration and frequency.

(b) Vibration in 6 d.f.; amplitude, frequency and duration

(c) Noise, frequency, intensity and duration

(d) Ambient radiation level.

(2) Hourly record; dump daily:

(a) Ambient temperature in containers.

(b) Relative humidity.

(c) Gas composition and pressures: Total pressure plus partial pressures of up to 10 gases, e.g., O_2, N_2, CO_2, CO, etc.

(d) Illumination verification: on/off, periodicity, intnesity.

(e) Rate of rotation of centrifuge.

(3) Dependent on design of experiment:

(a) Event actuation/termination, verification.

(b) Monitoring or critical experiments measurements, for example, below:

heart rate
ECG
Blood pressure
cardia output
O_2 content of blood
CO_2 content of blood
Respiration Rate
CO_2 output
Body Temperature

Body fluids composition (blood, urine, etc.)
Automated Manual with tape recording of data
EEG
EMG
Animala Activity

(c) Photographic film processing and storage.

(d) Automatic data and specimen reentry capsule - 1 per experiment.

(e) Specimen logistics return.

(f) Photograph logistics return.

(4) Ad hoc - only occasional:

(a) Photograph transmission by RF.

(b) Real time or near-real time TV.

7. DEVELOPMENT SCHEDULE

Phase	A	B	C	D	Flight
FY	69-70	70-71	71-72	73-74	75

8. COST

Total $1.8M (excluding centrifuge).

FY	69	70	71	72	73	74	75
$ in thousands	25	175	200	300	500	500	100

Phase	A	B	C	D	Data Reduction
$ in thousands	100	200	400	1000	100

EXPERIMENT DATA SHEET

THE ROLE OF GRAVITY IN GROWTH AND METABOLISM IN REPTILES

---Influence of low gravity upon turtle growth and metabolism

1. SPECIFIC OBJECTIVE

To determine the role of zero and low gravity on turtle growth, cardiovascular response, and metabolism. Determinations of circulation, fluid shifts and bone demineralization may also be attempted as follow-on research.

2. GENERAL DESCRIPTION

The proposed experiments would be designed to test the necessity of gravitational fields for growth and development of vertebrates. Gravity has long been recognized as necessary for normal growth of the higher plants. Recent studies at simulated high gravity confirm that this agent also influences normal animal growth.

Experiments in this laboratory indicate that gravity not only limits but also stimulates the growth of turtles. A slight increase in the gravity field can increase growth, a slower than normal growth might occur at zero-g. Development is likely to be more disorganized than normal. Statistical reliability will be controlled by comparison with the centrifuged controls in the satellite. Two experiments will be flown; the first would employ 12 turtles; 6 0-g and 6 1-g onboard controls. The number of animals needed for the second flight will be predicted from the results of the first flight and related ground-based studies. Statistical comparison will also be attempted with turtles grown in simulated low gravity by tumbling in devices which resemble clinostats.

The experiment would involve turtles subjected to weightlessness achieved by 30 or more days of orbital flight. A first experiment will require that control animals be centrifuged at 1.0 G within the satellite which contains experimental animals. If possible in the second experiment other centrifugal fields will be employed with additional turtles. The results will be compared with other Earth surface studies in a Hi-g centrifuge. Some or all of the animals will be labyrinthectomized so as to reduce rotational artifacts. Growth will be monitored by means of strain gauges mounted upon the shell. The shell will also serve as a mount for attachment of other sensing loads (such as those as for electrocardiographs) and for attachment of the animal to its housing. Follow-on experiments might include studies on metabolic rate, fluid shifts, and bone demineralization, but are not necessary in the first flight. Recovery of the turtles from the first flight although useful, will not be required. Recovery of live specimens from the more complex second flight will be important.

Future plans will involve a continued investigation of the role played by gravity in the control and guidance of growth, development, metabolism and related processes.

Onboard modification of experiment protocols during the second flight would provide an ideal means to implement such follow-on plans.

3. OPERATIONAL CONSTRAINTS

Impact of the total launch and reentry environments upon the test specimens must be minimized. Once in orbit, control of the acceleration environment is desirable. Engineering solutions to minimize transient "station connected" g-forces must be achieved. A research centrifuge

must be provided. Periodic phenomena, vibration, noise, unusual EM fields or other non-terrestrial phenomena must be quantified, recorded, and minimized. Altitude, inclination, and pointing are not critical.

4. <u>MODE OF OPERATION</u>

a. Automated on first flight.

b. Man attended and manipulated during the second flight.

c. If attached or integral: isolated from S/C acceleration.
If detached: dockable for manned access and operations.

d. Periodic operation of animal colony equipment with possible adaptation, modification, updating or replacement of equipment for modifications in research plan may be required for follow-on experiments.

5. <u>CREW SUPPORT</u>

a. Functions:

(1) Laboratory housekeeping, maintenance, and repair.

(2) Animal colony management.

(3) Experiment set-up.

(4) Monitor animal and equipment condition.

(5) <u>Ad</u> <u>hoc</u> research activities. (<u>Desirable</u> to enhance scientific value and responsiveness of experiment, <u>but not critical</u> to successful execution of basic experiment).

(a) Set-up follow-on experiments with:

(i) onboard adults

(ii) newly arrived animals.

(b) Common lab techniques, e.g., mass measurement, photography, fluid handling, media preparation.

(c) Gross anatomical examination.

(d) Programmed and ad hoc photography.

(e) Ad hoc TV monitoring in conference with ground based P.I.

(f) Install and operate EKG, arterial and venous pressure devices, cardiac output instrumentation, EEG, physiological and metabolic instrumentation, etc.

(g) "Dry" or "moist" chemistry for blood, urine and other body fluids.

(h) Prepare, fix, stain smears.

(i) Collect and preserve whole specimens.

(j) Dissect and preserve specimens. (possible option.)

(k) Isolate, fix, section, stain tissues. (possible option).

(6) Experiment termination.

(7) Specimen preparation for logistics return.

b. Time - For each major research activity of the classes below.

(1) Set up: First Exp., 1 hr; 2nd exp. 8 hrs.

(2) Housekeeping, maintenance, and repair (2nd experiment only): 1/4 hr. per day.

(3) Monitor equipment and animals: 5 min. per day.

(4) Research procedures (2nd experiment only): up to 2 hrs. per event.

(5) Termination (1st experiment) - turn off and pack - 1 hr; (second experiment) - sacrifice, dissect, preserve, pack for return: 8 hrs. per event.

c. Duty Cycle. (Requiring up to the suggested time depending on functions finally selected.)

(1) Assumptions:

(a) 2 experiments: 1st largely automated; 2nd man participation.

(b) Experiment duration: 90 days.

(2) Set up:

(a) 1 hr per event; 1 event

(b) 8 hrs. per event; 1 event

(3) Daily Routine:

(a) 5 min. per day; 90 days

(b) 1/2 hr. per day; 90 days

(4) Ad hoc research procedures: (second experiment only) - 2 hrs per event; 1 event per week; 12 weeks.

(5) Termination and packing:

(a) 1 hr per event; 1 event

(b) 8 hrs. per event; 1 event.

d. Skills: Gifted technical assistant, or if doing follow-on experiments, professional physiologist. See "Functions", para. 5.a.

e. Special training: Training as research associate with participating P.I.'s.

6. SPACECRAFT SUPPORT

(a) Including Experiment Equipment for Centrifuge and 0-g: Excludes weight, etc., of centrifuge itself. Based on estimated 1 container (6 turtles) at each of 2 acceleration levels. Total of 2 containers.

(1) Power: 30 watts continuous

(2) Volume:

(a) Specimens, housing and expendables: 2.0 ft^3

(2 units 1 ft^3 @)

(b) Ancillary research equipment: 0.5 ft^3

(3) Weight:

(a) Specimens, housing and expendables: 20 lbs.

(b) Ancillary research equipment: 5 lbs.

(4) Envelope:

(a) Specimens, housing and expendables: 2 units cubes 1 x 1 x 1 ft.

(b) Ancillary research equipment: To be determined - not critical.

b. 0-g Experiment Equipment Only:

Based on estimated 1 container (6 turtles) at 0-g only:

(1) Power: 15 watts continuous

(2) Volume:

(a) Specimens, housing and expendables: 1 ft^3

(b) Ancillary research equipment: nil

(3) Weight:

(a) Specimens, housing and expendables: 10 lbs.

(b) Ancillary research equipment: nil

(4) Envelope:

(a) Specimens, housing and expendables: 1 x 1 x 1 ft.

(b) Ancillary research equipment: nil

c. Data

(1) Continuous; dump each orbit:

(a) Accelerations in 6 d.f.; magnitude, duration and frequency

(b) Vibration in 6 d.f.: amplitude, frequency and duration

(c) Noise, frequency, intensity and duration

(d) Ambient radiation level.

(2) Hourly record; dump daily:

(a) Ambient temperature in containers

(b) Relative humidity

(c) Gas composition and pressures: Total pressure plus partial pressures of up to 10 gases, e.g., O_2, N_2, CO_2, CO, etc.

(d) Illumination verification: on/off, periodicity, intensity

(e) Rate of rotation of centrifuge

(3) Dependent on design of experiment:

(a) Rate of growth (strain gauge)

(b) Event actuation/termination, verification

(c) Monitoring or critical experiment measurements, for example, below:

G
heart rate
respiration rate
O_2 consumption
CO_2 output
animal activity

(d) Photographic film processing and storage

(e) Specimen logistics return.

(f) Photograph logistics return.

(4) Ad hoc - only occasional:

(a) Photograph transmission by RF.

(b) Real time or near-real time TV.

7. DEVELOPMENT SCHEDULE

Phase	A	B	C	D	Flight
FY	69-70	70-71	71-72	73-74	75

8. COST

Total: $1.825 M (excluding centrifuge)

FY	69	70	71	72	73	74	75
$ in Thousands	25	250	275	350	800	100	25

Phase	A	B	C	D	Date Reduction
$ in Thousands	100	250	550	900	25

EXPERIMENT DATA SHEET

THE ROLE OF GRAVITY IN EMBRYOGENESIS AND DEVELOPMENT IN AMPHIBIA
---The effect of sub-gravity on the frog egg, fertilized and developing in space

1. SPECIFIC OBJECTIVES

The principle objective is that of studying the effect of weightlessness on the sequentially exposed unfertilized, fertilized egg and embryo of the frog, *Rana pipiens*. Normality of division, differentiation and development will be studied grossly and microscopically.

2. GENERAL DESCRIPTION

Eggs and sperm of the frog *Rana pipiens* will be held separately in a stabilized state, before, during, and after launch until stable 0-g conditions have been achieved. Eggs will be fertilized in orbit to eliminate problems encountered in earlier trials due to pad holds and launch stress. After the astronaut has actuated the devices for mixing the sperm and eggs, different periods of time will be allowed to pass before the eggs, or embryos are killed and fixed for ground study. It is the intent to return some specimens to Earth to follow the course of their development. This requires that this 4½ day experiment be run probably during "crew change over" periods. The unit could be brought up on the upcoming logistics flight and sent down on the return flight.

The value or feasibility of the following approaches has not yet been considered:

(1) Leaving one group of specimens (Rana pipiens and/or Zenopus laevis) aboard the spacecraft in an appropriate life support unit to complete their full cycle of growth and metamorphosis.

(2) The elimination of potential stresses on the eggs and sperm due to excessive pad delays and launch environment factors by carrying adult frogs into orbit and obtaining eggs and sperm to set up both 0-g experimental, and 1-g centrifuge control zygotes.

Throughout the whole post-natal period, living and dead animals plus accumulated specimens would be periodically returned to Earth. However, these additional approaches are not considered in the following sections.

3. OPERATIONAL CONSTRAINTS

Impact of the total launch and reentry environments upon test specimens must be minimized. Once in orbit, control of the acceleration environment is necessary for the period following fertilization. Engineering solutions to minimize transient "station connected" g-forces must be achieved. A research centrifuge is desirable. Isolation from any periodical phenomena, vibration, noise, unusual EM fields or other non-terrestrial phenomena would be desirable but not absolutely necessary. All should be quantified, recorded, and minimized. Altitude, inclination and pointing are not critical.

4. MODE OF OPERATION

a. Man attended and manipulated.

b. If attached or integral: isolated from S/C acceleration.
   If detached: dockable for manned access and operations.

5. CRREW SUPPORT

a. Functions:

(1) Laboratory housekeeping, maintenance and repair.

(2) Experiment setup.

(3) Monitor specimen condition.

(4) Initiate experiment events.

(5) Verify events.

(6) Ad hoc research activities (Desirable to enhance scientific value and responsiveness of experiment, but not critical to success of basic experiment).

(a) Setup follow-on experiments with: (possible future option)

(i) pro[illegible]

(ii) onboard adults

(iii) newly arrived animals

(b) Common lab techniques, e.g., mass measurement, photography, fluid handling, media preparation.

(c) Gross anatomical examination.

(d) Collect and preserve whole specimens.

(e) Programmed and ad hoc photography.

(f) Ad hoc TV monitoring in conference with ground based P.I.

(g) Preserve specimens.

(h) Isotopic tracers techniques - administration and detection.

(7) Experiment termination.

(8) Specimen preparation for logistics return.

b. Time: For each major research activity of the classes below:

(1) Set-up: 1 hour.

(2) Monitor equipment and animals: 1/4 hr/day.

(3) Research procedures: 1/4 hr. to 2 hrs. per event.

(4) Termination: Sacrifice, preserve, pack for return: up to 8 hours per event.

c. Duty Cycle: (Requiring up to the suggested time depending on functions finally selected.)

(1) Assumptions:

(a) 1 package at 0-g; 1 package at 1-g.

(b) 3 replicates of basic; or 1 basic plus 2 follow-on experiments.

(c) Basic experiment duration 4½ days.

(d) Follow-up experiments of 90, 180, and 270 days respectively.

(2) Setup:

(a) 3 events; 1 hr. per event.

(b) 3 events; 4 hrs. per event.

(3) Daily routine:

(a) Basic experiments: 1/4 hr. per day; 5 days.

(b) Follow-on experiments 1/4 hr. per day; 90, 180, 270 days.

(4) Ad hoc research procedures:

(a) Basic experiments: 1/4 hr. per event.

(b) Follow-on experiments: up to 1 hr. per event; 1 event per week; 40 weeks.

(5) Termination

(a) Basic experiments: 3 events; 2 hrs. per event.

(b) Follow-on experiments: 3 events; 8 hrs. per event.

d. Skills: Technical assistant unless more advanced options are exercised. Then requires professional physiologist or MD.

e. Special training: Training as research associate with participating P.I.'s.

6. SPACECRAFT SUPPORT

a. Including Experiment Equipment for Centrifuge and 0-g:

Minimum experiment only.

Excluding weight, etc., of centrifuge itself.

Based 1 package at each of 2 acceleration levels 0-g and 1.0g.

Total of 2 units.

(1) Power:

(a) Average: 30 watts

(b) Peak: 40 watts

(2) Volume:

(a) Specimens, housing and expendables: 3.2 (2 units 1.6 ft^3 @)

(b) Ancillary research equipment: None

(3) Weight:

(a) Specimens, housing and expendables: 80 (2 units at 40 lbs @)

(b) Ancillary research equipment: None

(4) Envelope:

(a) Specimens, housing and expendables: 2 units; cube - 1 1/4 x 1 1/4 x 1 1/4 ft.

(b) Ancillary research equipment: None

b. 0-g experiment equipment only:

Based on 1 package at 0-g only:

(1) Power:

(a) Average: 15 watts

(b) Peak: 20 watts

(2) Volume:

(a) Specimens, housing and expendables: 1.6 ft^3

(b) Ancillary research equipment: none

(3) Weight:

(a) Specimens, housing and expendables: 40 lbs.

(b) Ancillary research equipment: none

(4) Envelope:

(a) Specimens, housing and expendables: 1 1/½ ft. x 1 1/4 ft x 1 1/½ ft.

(b) Ancillary research equipment: N/A

c. Data

(1) Continuous; dump each orbit:

(a) Accelerations in 6 d.f.; magnitude duration and frequency

(b) Vibration in 6 d.f.: amplitude, frequency and duration

(c) Noise, frequency, intensity and duration

(d) Ambient radiation level.

(e) Temperature (minimum 40 times per day)

(2) Hourly record; dump daily:

(a) Relative humidity

(b) Gas composition and pressures: Total pressure plus partial pressures of up to 10 gases, e.g., O_2, N_2, CO_2, CO, etc.

(c) Illumination verification: on/off, periodicity, intensity

(d) Rate of rotation of centrifuge

(3) Dependent on design of experiment:

(a) Event actuation/termination, verification

(b) Monitoring or critical experiment measurements, for example below

O_2 consumption

CO_2 producation

p^H of medium

(c) Photographic film processing and storage

(d) Specimen logistics return

(e) Photograph logistics return.

(4) Ad hoc - only occasional:

(a) Photograph transmission by RF.

(b) Real time or near-real time TV.

7. DEVELOPMENT SCHEDULE

Phase	A	B	C	D	Flight
FY	Completed	69-70	71	71-73	75

8. COST

Total: $0.9 M (excluding centrifuge)

FY	69	70	71	72	73	74	75
$ in Thousands	25	25	200	200	350	50	50

Phase	A	B	C	D	Data Reduction
$ in Thousands	-	50	150	650	50

FUNCTIONAL PROGRAM ELEMENT IV

PLANT SPECIMENS (BIO E)

1. RELATED DISCIPLINE - Space Biology (Bioscience)

2. PROGRAM ELEMENT - Plant Specimens (Bio E)

3. REQUIREMENT

Extend the survey and in-depth study of the responses of a variety of plant species evolving from results gained in the Biosatellite Program toward plans for research in the Manned Space Station.

4. JUSTIFICATION

a. The biological scientific community has identified a need for these data arising from both survey and in-depth experimentation.

b. The manned space flight and bioscience communities have endorsed this activity as a means for evolving a flexible, responsive, and powerful mode of carrying out research on the above test subjects in the Manned Space Station.

c. The capability of long-term space systems to meet the environmental needs and the spacecraft support requirements must be evaluated in the operational environment, e.g., (1) provision of a very low acceleration environment; (2) isolation of certain plant experiments from rhythmic or cyclic phenomena.

d. The ability of man to initiate, monitor and terminate experiments as well as to maintain and repair equipment must be demonstrated operationally. For example, the capability of the scientist/crewmanmust also be tested to determine whether he can (1) receive plant seeds, seedlings tissues or other plant material (2) perform in-flight preparation of plant materials for (3) installation in on-board modules, (4) make direct observations, photgraphs, or recordings on the test material, (5) perform numerous

specimen collection and preservation techniques including macro dissection for particular organs or tissues, (6) make serendipitous or ad hoc demand observations, (7) modify experiment protocol and conditions and (8) terminate plant experiments, preparing both live specimens and preserved material for logistics return. The requirement for, and role of, a plant physiology/morphology specialist in a space station must be determined in operational tests.

e. Technological requirements must be satisfied (1) for the evolution of plant research equipment for incorporation in the "Biotechnology Lab" now under study by OART; and (2) in the area of providing a low-g and low vibration research environment free of rhythmic "cue" phenomena.

5. COMPONENT EXPERIMENTS

The experiment selections and descriptions given herein are only typical. They are in no way intended to indicate the final selections or formats. They are given here only to permit planners to assess the impact of a typical plant research Functional Program Element on the total space flight system.

a. Plant responses form 0 to 1 G

b. Pea seedling growth in orbit.

c. Plant morphogenesis under weightlessness

d. Effect of weightlessness on gemetogenesis and morphogenesis of Pteris gametophytes

e. Role of auxin mediated reactions in the developing wheat seedling during weightlessness

f. Role of gravitational stress in land plant evolution: the gravitational factor in lignification

g. Effect of geophysical factors on circadian rhythms in plants

(1) Studies on the circadian leaf movements of pinto beans

(2) Environmental factors regulating circadian rhythms in Phaseolus leaves

6. DESCRIPTION

Bio E is a cluster of plant experiment modules grouped together on the basis of commonality in: equipment requirements, support requirements, research approaches, and specimen handling and observation techniques.

a. Approximate Characteristics:

(1) Employing On-board Centrifuge

(a) Weight: 327 lbs.

(b) Volume: 24.4 ft^3

(c) Power:

(i) Average: 500 Watts

(ii) Peak: 710 Watts

(d) Cost: $9.13 M

(2) 0-g Program Only:

(a) Weight: 155 lbs.

(b) Volume: 10.1 ft^3

(c) Power:

(i) Average: 200 Watts

(ii) Peak: 400 Watts

(d) Cost: $9.13 M

b. On-board Research Centrifuge.

The experiments comprising this Functional Program Element would be significantly enhanced by and ability to have an on-board acceleration device capable of imposing constant levels of acceleration between 1 g equivalent and the lowest values practical to provide. Traditionally

one thinks of a conventional centrifuge to provide such acceleration fields although other techniques might prove more desirable in the space station situation.

(1) Research Advantages:

The concept of a "centrifuge" capability offers three major advantages over flying "zero g" experiments alone. First, the in-flight 1 g control material will experience the launch and recovery acceleration and vibration which cannot be faithfully reproduced on ground based instrumentation. It will also experience the vibration and transient acceleration pulses, during orbit, simultaneously with the "zero g" experiemntal package. At the present time these factors must be studied with separate control groups. Even here the control specimens cannot be exposed to representative vibrations in more than one plane simultaneously. Some of the early results of space flight observed on biological material, and attributed to "weightlessness" have since been identified as resulting from launch and recovery vibration profiles. While some of these factors may be partially clarified by the mid 1970 period, it is certain that many factors will remain unresolved. Thus providing in-flight one g controls will markedly reduce the time and cost of the multiple ground controls now required to interpret the results of space flight experiments. The second advantage is the potential for firmly

establishing whether the clinostat often used in plant research is a valid simulation of the free fall or weightless environment. Some of the results of the Biosatellite experiments are in agreement with those obtained on ground based "null gravity" studies done using a rotational device in which the resultant gravity vector is zero. Other results do not agree and there is little certainty that "zero g" simulators on the ground faithfully represent the "gravity free" situation of orbital space flight.

The third advantage rests in the ability to expose plants and animals to accelerative fields between 0 and 1 g. Thus an early approach to establishing "threshold" responses can be profitably undertaken. We do not know enough about the difference in response to acceleration to define threshold studies. Both phenomens and rough boundaries must be determined in preliminary experiments before in depth investigations can be begun.

The first generation of experiments will not require the sophistication and complexity of one designed for high density payloads with very precise and complex data acquisition. The required performance characteristics outlined below can be met with a comparatively simple centrifuge that should not impose a heavy demand upon the space station stabilization subsystems. Also the experiments outlined

in this FPE, which would be flow on the centrifuge should not impose intolerable time and effort requirements on the crew.

(2) Centrifuge Characteristics:

This considers both D & E type experiments. The maximum figures will accommodate the largest proposed experiment in either group.

(a) Radius: Largest feasible radius is desired; a minimum of 10 ft. would satisfy most all experiments.

(b) Rotation rate: A minimum range of 17 r.p.m. lowered to 1 r.p.m. is required. Based on 10 ft. radius this would provide "g" levels from 1 to 3.4×10^{-3} at the outer limit of the arm.

(c) Load Requirements: Minimum equivalent of 1-25 lb. experiment packages per radial arm.

(d) Radial Loading: Assume maximum acceleration of 1.5 g with 1-25 lb. package at 10 ' $\pm$ 37.5 lbs. per radial arm.

(e) Number of arms. Minimum of 6. If dual contra-rotating heads, 4 per head to facilitate balancing.

(f) Angular acceleration: No minimum or maximum requirement. Should be low but with rapid braking capability for emergency. Rate monitored.

(g) Vibration: Minimal vibration at all speeds. Vibrations at experimental modules to be monitored. Centrifuge need not be isolated from transient acceleration and vibration of spacecraft.

(h) Operating time: Capable of continuous operation up to 300 days. Short interruptions are acceptable to most experiments.

(i) On-Board Data Requirements

Minimum:

Temperature, humidity, gas pressure, and composition, and verification of satisfactory operation of each package hourly. Vibration and all transient and steady state acceleration and rotation rate continuous with daily data dump.

(j) Special considerations:

(i) Electrical Interfaces.

(aa) Power must be provided for lighting and other environmental controls.

(bb) Data accumulated by slip rings or induction techniques if telemetry is not feasible.

(cc) TV telemeter link for visual observation of selected experiments.

(dd) EEG telemeter link. EKG etc.

(ii) Mechanical Interfaces.

All experiment packages must be oriented with respect to ground vertical during launch and

recovery. Therefore they must be either rotated on the centrifuge or attached to the arms in proper orientation after attaining orbit. Early start-up is required. Package attachment must be by simple positive fasteners.

Active cooling required for selected experiments. Experiment packages currently planned with individual gaseous environment controls, i.e. 15 psi 80/20, N_2/O_2. Central supply would lighten packages on centrifuge. Requirement applies to launch and recovery as well as to experimental period.

(iii) Accessibility

Centrifuge must be accessible so scientist-astronaut can initiate and service experiments (as required) and remove experimental material and/or data packages to prepare for sample return.

(iv) Isolation from cyclic cues resulting from space station activity.

(3) <u>DEVELOPMENT SCHEDULE</u>

Phase	A	B	C	D	Flight
FY	70	71	72	73-74	75

(4) <u>COST</u>

Total $7.0

FY	69	70	71	72	73	74
$ in thousands	-	200	300	1500	2500	2500
Phase	A	B	C	D		
$ in thousands	200	300	1500	5000		

c. Bio E appears the most likely of the life sciences FPE's to require (if at all) complete isolation from the parent space station at times. However, the experiments must be available to man frequently if his abilities are to be exploited. An independent, dockable experiment module will be under detailed study in the near future. No characteristics are yet available. The requirements of Bio E should be made to impact module design as early as possible in case such a module becomes necessary for some types of plant research in space.

d. Variable packaging geometry can be used.

e. Envelope is undefined.

f. Individual experiment developments are independent of the development of both the space station and Bio E program element.

7. SPECIAL CONSIDERATIONS

a. Minimization of acceleration vibration and noise in magnitude (or intensity), duration, and frequency of exposure (6 d.f.)* is required. (see 7 a)

b. Continuous record of accelerations (6 d.f.) vibrations and noise is required. (see 7 a)

c. Isolation from all periodic or rhythmic phenomena (vibration, noise, thermal, etc.) is required.

d. Onboard centrifuge is desirable (0.1-1/g) both as an onboard flight control and a research tool as described in appendix.

e. Multipurpose photographic capability required for both microscopic and macroscopic objects in both planned and ad hoc research operations.

f. Real-time RV or near-real-time video tape capability desirable for ad hoc observation by ground based P.I. of experiment equipment, procedures, and both microscopic and macroscopic specimens.

g. The plant facility will require an environmental control systems separate from the spacecraft system if a common system is used for all experiments.

h. Scientist-astronaut work space for manipulation of experiments, ancillary equipment and specimens must be provided as a part of the FPE. Capability to pressurize the workspace to sea level atmospheric conditions must be provided if onboard scientist is to manipulate specimens in the workspace outside of their containers appropriate operational doctrine to permit scientist to do useful work during his decompression periods must be developed.

EXPERIMENT DATA SHEET

PLANT RESPONSES FROM 0 to 1 G.

1. SPECIFIC OBJECTIVE

The objectives of this experiment are to analyze the growth processes of plants and measure their morphological, biochemical, and physiological responses to intermediate gravitational forces ranging from almost zero to one G for an extended period of time. The responses of the plants can used to elucidate the role of gravity on Earth in normal plant development and metabolism. If a centriguge is not available to provide 0-1 g environments, the basic 0 g experiment will be carried out.

2. GENERAL DESCRIPTION

The experimental design as currently envisaged consists of germinating and growing wheat in space while artificially inducing gravitational forces of several intensities. This can be accomplished through the use of a centrifuge. By placing the seedlinga at varying distances from the center of rotation along a radial arm, centrifugal forces of differing intensities can be induced since the centrifugal force experienced at any point is a function of the rotational velocity and the length of the radius. For reasons of stability (and numbers of experimental plants) two centrifuges rotating at the same speed but in opposite directions are contemplating. The size of centrifuge will depend upon the vehicle used and the available space allocated to this experiment.

Size, orientation, cellular physiology, and biochemical activities will be used to score the effects. Ground based control experiments with seedlings cultured in a similar fashion and both on a horizontal

clinostat and normal to gravity will also be conducted. Differences in functional processes between those plants grown in space from the control specimens will provide additional evidence for the response of the growth processes to reduce gravitational forces. Photographic records of the plant organs as they have developed during experimental periods can be used for precise measurements of several criteria of root and coleoptile orientation. It will be possible to distinguish degrees of changes in orientation with varying gravitational forces as such differences appear in the growth responses during orbit. Biochemical analyses will be made later of the same seedlings after the photographs have been taken and the tissues preserved.

The enzymes selected for analysis are representative of the major pathways of metabolism and energetics. Glyceraldehyde-3-phosphate dehydrogenase appears to be the most amenable to microanalytic techniques of those enzymes in the glycolytic pathway, while glucose-6-phosphate dehydrogenase will indicate changes in the oxidative pathway of carbohydrate metabolism and malic acid dehydrogenase will cover the tricarboxylic acid cycle. DPN-cytochrome-C-reductase was chosen as the enzyme of choice to study the electron transport system since it is also linked to the crossover site for the conversion of ADP to ATP. Peroxidase is included in this study for its association with the destruction of auxin and its adverse effect upon the election transport system. Measurement of enzyme activity and reaction constants will provide critical information relating to the effect of weightlessness on the growth processes, the effects

on protein sturcture and, concomitantly, enzyme activity. Any suggestion of a particular metabolic pathway being affected by weightlessness as judged from the results obtained from the Biosatellite data will certainly influence the course of this study. Every effort will be made to utilize the knowledge gained from our present studies.

The analytical techniques required for the successful acquisition of data have already been established. Preliminary studies with the above enzyme systems have already been initiated under the Biosatellite program. The data obtained from the three day orbital flight will then be compared with those obtained from a flight of longer duration. Moreover, the information currently being acquired will provide insight into the determination of which of the intermediary pathways of metabolism will require more concentrated study. It may be possible for a scientist astronaut to repeat or modify research protocols using on-board reuseable/adaptable equipment to follow immediately the most profitable leads obtained during the flight.

Twenty-four containers adapter from the Biosatellite hardware would be utilized. Each one, containing one wheat seed stalk, will be mounted on an on-board centrifuge and spaced so that the desired intensity of gravitational force is obtained by varying the distance of the seed containers from the axis and adjusting the speed of rotation. Six foot arms rotating at 22 rpm results, for example, in a one g acceleration at the tip. If containers are spaced at one foot intervals, using the six foot arm of this speed, gravitational forced of approximately

0.2 g, 0.4 g, 0.6, 0.8 and 1.0 g are obtained. Lower levels may be required for studies of the geotropic threshold. Counter-rotation of the arms would balance the induced torque on the system and the four arms would allow identical centrifugal forces to be imposed on four containers simultaneously at each position about the center of rotation. Heater blankets are required for each container and will function as heat source as well as incubator to control the temperature environment of the seed growth. Heat input must be equally distributed to all sides of the container for proper seed germination and eliminate the restricted growth presently experienced. Thermistors are required for monitoring and controlling temperature within the prescribed limits of 70° ± 5°F.

3. OPERATIONAL CONSTRAINTS

Impact of the total launch and reentry environments upon test specimens must be minimized. Once in orbit, control of the acceleration and vibration environment is necessary. Engineering solutions to minimize transient "station connected" g-forced must be achieved. Flight on an independent but dockable module may be required. A research centrifuge is desirable to miximize scientific return but is not critical to the success of a valid 0-g experiment. Periodic phenomena, vibration, noise, unusual electromagnetic fields or other nonterrestrial phenomena must be quantified, recorded, and minimized. During orbital flight altitude, inclination and pointing are not critical. However, during launch and reentry the direction of g forces will be cirtical to avoid compromising the experiment or damaging the specimens.

4. MODE OF OPERATION

a. Man attended and manipulated.

b. If attached or integral: isolated from spacecraft acceleration. If detached: dockable for manned access and operations.

c. Possibility of experiment repetition or modification, and reuse, updating, or replacement of equipment for advancement in research plans.

5. CREW SUPPORT

A. Functions:

(1) Laboratory housekeeping, maintenance and repair.

(2) Experiment set up.

(3) Monitor plant and equipment condition.

(4) Ad hoc research activities. (Desirable to enhance scientific value and responsiveness of experiment, but not critical to successful execution of basic experiment).

(a) Set up follow-on experiments with:

(i) on board seed stocks

(ii) newly arrived seeds

(b) Common lab techniques e.g. mass measurement, fluid handling, media preparation.

(c) Gross morphological examination.

(d) Programmed and ad hoc photography.

(e) Ad hoc TV monitoring in conference with ground based P.I.

(f) Install and operate plant physiological and metabolic instrumentation, etc.

(g) "Dry" or "Moist" chemistry for semiquantitative and qualitative tests.

(h) Collect and preserve whole specimens.

(i) Dissect and freeze specimens (ambient dry ice LN_2)

(5) Experiment termination.

(6) Specimen preparation for logistics return; package experiments, samples, or photographs and other records for return to Earth.

b. Time - For each major research activity:

(1) Set-up 8 hrs.

(2) Laboratory housekeeping: 1/4 hr per day

(3) Monitor equipment and plants - 1/4 hr per day.

(4) Research procedures - up to 8 hrs per event.

(5) Termination - dissect, freeze, pack for return - 8 hrs.

c. Duty cycle: (Requiring up to the suggested time depending on functions finally selected).

(1) Assumptions:

(a) 3 experiment periods

(b) Experiment duration: 21 days approximately

(2) Set up: 8 hrs per event, 3 events

(3) Daily routine: 1/2 hr per day; 63 days

(4) Ad hoc research procedures: 8 hrs per event; 4 events per experiment; 3 experiments.

(5) Termination and packing: 8 hrs per event; 3 events.

d. Skills: Professional plant physiologist or gifted technical assistant. See "Functions," paragraph 5.a.

e. Special training: Training as research associate with participating P.I.'s.

6. SPACECRAFT SUPPORT

a. Including experiment equipment for centrifuge and Og: excludes weight of the centrifuge itself. Based on estimated 4 reuseable modified Biosatellite wheat seedling growth units (each containing a 12-seed holder) at each of 6 acceleration levels, 0 g, 0.2 g, 0.4 g, 0.6 g, 0.8 g, 1.0 g. Total of 24 units.

(1) Power - 100 watts continuous.

(2) Volume

(a) Specimens, containers and expendables: 6.0 ft^3 (0.25 ft^3 per unit).

(b) Ancillary research equipment: 0.5 ft^3

(3) Weight:

(a) Specimens, containers and expendables: 48 lbs. (2.0 lb per unit).

(b) Ancillary research equipment: 10 lbs.

(4) Envelope:

(a) Specimens, containers and expendables: 24 containers, each 6 x 6 x 12 in.

(b) Ancillary research equipment: to be determined - not critical.

b. 0-g Experiment Equipment Only

Based on estimated 4 modified Biosatellite wheat seedling growth units (as above) at 0-g.

(1) Power: 16 watts continuous (each 4 watts per unit)

(2) Volume:

(a) Specimens, containers and expendables: 1 ft^3 (0.25 ft^3 per unit)

(b) Ancillary research equipment: 0.5 ft^3

(3) Weight:

(a) Specimens, containers and expendables: 8 lbs.

(b) Ancillary research equipment: 10 lbs.

(4) Envelope:

(a) Specimens, containers and expendables: 4 containers, each 6 x 6 x 12 in.

(b) Ancillary research equipment: To be determined - not critical.

c. Data:

(1) Continuous: dump each orbit:

(a) Accelerations in 6 d.f.: magnitude, duration and frequency

(b) Vibration in 6 d.f.: amplitude frequency and duration.

(c) Noise frequency, intensity and duration.

(d) Ambient radiation environment.

(2) Hourly record; dump daily

(a) Temperature

(b) Relative humidity

(c) Gas composition and pressures: e.g. O_2, CO_2, N_2, CO, ethylene, etc.

(d) Illumination verification: on/off, periodicity, intensity.

(e) Rate of rotation of centrifuge.

(3) Dependent on design of experiment:

(a) Event actuation/termination verification

(b) Specimen logistics return

(c) Photograph logistics return.

(4) Ad hoc - only occasional:

(a) Photograph transmission by RF.

(b) Real-time or near-real-time TV.

7. DEVELOPMENT SCHEDULE

Phase	A	B	C	D	Flight
FY	70	71	72	73-74	75

8. COST

Total: \$1.35 M (excluding centrifuge)

FY	69	70	71	72	73	74	75
\$ in thousands	-	50	100	250	500	400	50

Phase	A	B	C	D	Data Reduction
\$ in thousands	50	100	250	900	50

EXPERIMENT DATA SHEET

PEA SEEDLING GROWTH IN ORBIT

1. SPECIFIC OBJECTIVE

We propose to analyze the growth processes of a representative dicotyledonour plant in relation to its adaptations to the force of gravity during the evolution of terrestrial plants. The goal resembles that for the wheat seedling experiment of the Biosatellite Program except that the pea seedling will provide information about the morphology, histology and physiology of a typical, dicotyledonous leaf, secondary root, elongating stem and the characteristic "hook" at the tip of the seedling stem. This experiment is to be carried out at various g-levels using an on-board centrifuge. If the centrifuge is not available, the basic 0-g experiemnt will be carried out.

Growth of pea seedlings in an orbiting satellite may confirm the clinostat as a device for obtaining plant organs as they are formed without the influence of gravity. Diverse results from this experiment will call attention to the need for growing various kinds of plants in orbiting laboratories in order to establish the basic science of plant growth and the applied science of plant culture in space vehicles.

2. GENERAL DESCRIPTION

The growth of seedling shoots and roots with all acceleration forces below the threshold of sensitivity will provide several criteria of weightlessness and low - g effects including size, orientation, structure, chemical constituents and enzyme activities. Ground control experiments will be conducted simultaneously with seedlings in the same culture system,

both erect to gravity and rotating on a horizontal clinostat at the same temperature. Details of form and functional processes found in recovered orbital plants and absent from the controls will provide unique evidence for the adaptation of growth processes to gravitational force.

The validity of conclusions will be supported by the development of the plants under 0 to 1 G, since orbit will have been attained before seedling organs have been formed. The embryo will be protected from injurious vibrations during launch by the damping action of the seed holders. The formative stages of germination will be free of vibration and significant acceleration and of variations in nutrition, water supply and such periodic illumination as may be used to prevent etiolation in the shoot.

Before launch the pea seeds will be surface sterilized, after attaining orbit they will then be soaked in distilled water before planting in a special holder system. A reservoir of water is held in a matrix of fine vermiculite that holds and delivers water to seeds and seedlings as they germinate. The seedlings develop in moist chambers formed by a plastic cylinder around each stalk of seeds, with the chamber wall far enough from the seeds to allow growth of most of the organs without contact with solid objects. Experience with the wheat seedlings ensures biocompatibility of seedlings and the flight hardware. The method of suspension of the seeds also alternates the stresses of reentry, so that the seedlings can be retrieved in the form in which they have grown during orbit.

For studies of morphology and orientation of seedlings organs, the set of seedlings will be photographed with apparatus adapted to the form and size of the largest seedlings. Direct measurements of significant dimensions of organs will also be taken before they are used for tissue work.

The data for analysis of size, form and organ orientation will be obtained from the photographs by the system developed for the Biosatellite wheat seedling experiment, suitably modified for pea seedlings. Coordinates of position in three dimensions with reference to the seed axis will be obtained from the projection of each picture on a wall at some distance from the slide projector. Orientation of parts will be described initially by angles computed from the X, Y and Z coordinates. Interpretation of these data for size and orientation of organs from the orbital experiment will be based on comparisons with the corresponding data from erect and clinostat ground controls.

Other studies of differences in physiological processes during orbit will be made by histological and biochemical methods. The presence and localization of key enzymes will be a mojor feature of the scoring system for weightlessness effects on metabolic processes. Distribution of starch and other carbohydrates may be found to be useful criteria in view of the statolith theory of graviperception by which the position of starch grains and other particles within receptor cells helps to determine the orientation of roots and stems.

Periodically some of the seedlings will be fixed and preserved, both to permit evaluation of serial changes during the growth period and to eliminate any possible physiological and chemical changes during reentry and retrieval.

3. OPERATIONAL CONSTRAINTS

Impact of the total launch and reentry environments upon test specimens must be minimized. Once in orbit, control of the acceleration environment is necessary. Engineering solutions to minimize transient "station connected" g-forces must be achieved. A research centrufuge is desirable to maximize scientific return but is not critical to the success of a valid 0-g experiment. Flight in an independent, dockable module may be required. Periodic phenomena, vibration, noise, unusual electromagnetic fields or other nonterrestrial phenomena must be quantified, recorded, and minimized. During orbital flight altitude, inclination and pointing are not critical. However, during launch and reentry the direction of g-forces will be critical to avoid compromising the experiment or damaging the specimens.

4. MODE OF OPERATION

a. Man attended and manipulated if seeds planted after launch or seedlings fixed before return to Earth.

b. If attached or integral: isolated from spacecraft acceleration. If detached: dockable for manned access and operations.

c. Possibility of experiment repetition or modification and reuse updating or replacement of equipment for advancement of research plans.

5. CREW SUPPORT

a. Functions:

(1) Laboratory housekeeping, maintenance and repair.

(2) Experiment set up.

(3) Monitor condition of plants and equipment.

(4) Ad hoc research activities. (Desirable to enhance scientific value and responsiveness of experiment, but not critical to successful execution of basic experiment.)

(a) Set up follow-on experiments with newly arrived seeds.

(b) Common lab techniques e.g., mass measurement, fluid handling, media preparation.

(c) Gross morphological examination.

(d) Ad hoc manual photography at request of P.I.

(5) Experiment termination.

(6) Specimen preparation for logistics return; package experiments, samples, or photographs and other records for return to Earth.

b. Time - For each major research activity:

(1) Set - up - 8 hrs

(2) Laboratory housekeeping: 5 min. per day.

(3) Monitor equipment and plants: 5 min./day

(4) Research procedures: up to 2 hrs/per event.

(5) Termiantion, photograph, preserve, pack for return: 8 hrs.

c. Duty Cycle: (Requiring up to the suggested times depending on functions finally selected)

(1) Assumptions:

(a) 3 experiment periods

(b) Duration: 14 days each.

(2) Set up: 8 hrs per event; 3 events

(3) Daily routine: 10 min. per day; 42 days

(4) Ad hoc research procedures 2 hrs per event; 1 event per day; 14 days per experiment period; 3 periods.

(5) Termination and packing: 8 hrs per event; 3 events.

d. Skills: Professional plant physiologist or gifted technical assistant. See "Functions," paragraph 5.a.

e. Special training: Training as research associate with participating P.I.'s.

6. SPACECRAFT SUPPORT

a. Including experiment equipment for centrifuge and 0-g: Excludes weight of centrifuge itself: Based on estimated 1 modified Biosatellite wheat seedling growth units (each containing 4 9-seed holders), at each of 2 acceleration levels 0-g and 0.2 g. Total of 2 units.

(1) Power: 50 watts (25 watts/unit) continuous, 60 watts (30 watts/unit) during peak loads.

(2) Volume:

(a) Specimens, containers and expendables: 2 ft^3 (1 ft^3/unit)

(b) Ancillary research equipment: 0.5 ft^3

(3) Weight:

(a) Specimens, containers and expendables: 30 lbs. (15 lbs/unit)

(b) Ancillary research equipment: 10 lbs.

(4) Envelope:

(a) Specimens, containers and expendables: 2 units at 1 x 1 x 1 ft.

(b) Ancillary research equipment: To be determined - not critical.

b. 0-g Experiment Equipment Only: Based on 1 modified Biosatellite wheat seedling growth units (as above) at 0-g.

(1) Power: 25 watts continuous, 30 watts peak.

(2) Volume:

(a) Specimens, containers and expendables: 1 ft^3

(b) Ancillary research equipment: 0.5 ft^3

(3) Weight:

(a) Specimens, containers and expendables: 15 lbs.

(b) Ancillary research equipment: 10 lbs.

(4) Envelope:

(a) Specimens, containers and expendables: 15 lbs.

(b) Ancillary research equipment: To be determined - not critical.

c. Data:

(1) Continuous; dump each orbit:

(a) Accelerations in 6 d.f.: magnitude, duration and frequency

(b) Vibrations in 6 d.f.; frequency, amplitude and duration.

(c) Noise frequency, intensity and duration.

(d) Ambient radiation environment.

(2) Hourly record; dump daily:

(a) Temperature

(b) Relative humidity

(c) Gas composition and pressures: e.g. O_2, CO_2, N_2, CO etc.

(d) Rate of rotation of centrifuge

(3) Dependent on design of experiment:

(a) Event actuation/termination verification

(b) Automatic data and specimen reentry capsule
1 per experiment.

(c) Specimen logistics return

(d) Photograph logistics return.

(4) <u>Ad hoc</u> - only occasional:

(a) Photograph transmission by RF.

(b) Real-time or near-real-time TV.

7. DEVELOPMENT SCHEDULE

Phase	A	B	C	D	Flight
FY	69-70	70	71	72-74	75

8. COST

Total: $1.15 M (excluding centrifuge)

FY	69	70	71	72	73	74	75
$ in Thousands	25	175	200	300	400	25	25

Phase	A	B	C	D	Data Reduction
$ in Thousands	20	150	200	725	25

EXPERIMENT DATA SHEET

PLANT MORPHOGENESIS UNDER WEIGHTLESSNESS

1. SPECIFIC OBJECTIVE

The objective of this experiment series is to follow up and expand upon the results obtained using the plant Arabidopsis in ground laboratory research. The requirements for specific advanced experiment hypotheses which need testing must await the results of a space flight in which a higher plant will have been grown through its full time in the weightless environment. THis experiment is to be carried out using an on-board centrufuge. If the centrifuge is not available, the basic 0-g experiment will be carried out.

2. GENERAL DESCRIPTION

The general hypothesis on which current flight research is planned with this plant are based, is that the pattern of development of a higher plant, if it grows under the condition of weightlessness, will differ qualititively and quantitatively from patterns which arise from growth in a normal gravitational field on Earth or on a clinostat. However, the mechanism whereby gravity directs plant morphogenesis is unknown. Much descriptive information on the effects of subnormal g fields is needed. Results of clinostat experiments and of satellite experiments can complement each other in elucidating the presently obscure mechanism of morphogenesis in a biological system which is patently responsive to gravity. Subnormal gravity can only be obtained in a space experiment.

Specimens of Arabidopsis will be cultured on agar in transparent containers and photographed intermittently with two cameras to provide stereo and time-lapse records of morphological changes during growth).

Either film recovery or RF transmission of the photographic information at a rate of about one frame per revolution in orbit will be required. Control data will be obtained on the ground with and without use of a clinostat. Biological material will be recovered and anatomical and cytological examinations will extend the study to other morphological levels with the same objectives in mind.

Records will be obtained from space flight studies in 3 spatial dimensions on the time course of development of the plant over selected critical portions of its life cycle. This record will very probably demonstrate "abnormalities" in gross morphology which will serve as indication of some of the mechanisms which have been altered at the level of basic histology and cytology. The extent of the departures from normal morphology cannot be predicted at present. Estimated reliability ought to be very high (over 90 per cent). In later flight experiments, on the basis of these results, specific periods as those of flower-bud formation, pollen maturation, fertilization and embryogenesis will be subjected to in-depth study to discover basic mechanisms by which the abnormalities arise. In order to do this, follow-on experiments will include study of the plant at several g levels intermediate between 0 and 1 g, possibly for several serial generations. The duration of exposure of a plant to a particular g environment to produce onset or a specific degree of abnormality will also be a necessary approach. Serial sampling of the plants during the course of the experiment and return of all survivors to Earth will be necessary to permit post-flight morphological, histological and biochemical analysis.

3. OPERATIONAL CONSTRAINTS

Impact of the total launch and reentry environments upon test specimens must be minimized. Once in orbit, control of the acceleration environment is necessary. Engineering solutions to minimize transient "station connected" g-forces must be achieved. Flight in an independent but dockable module may be required. A research centrifuge is desirable to maximize scientific return, but is not critical to the success of a valid 0-g experiment. Periodic phenomena, vibration, unusual electromagnetic fields or other non-terrestrial phenomena must be quantified recorded and minimized. During orbital flight altitude, inclination and pointing are not critical. However, during reentry the direction of g-forces may be critical to avoid compromising the experiment or damaging the specimens.

4. MODE OF OPERATION

a. Man attended for logistics purposes only

b. If attached or integral: isolated from spacecraft acceleration.

c. If detached: dockable for manned access and operations.

c. Possibility of experiment repetition via logistics replacement of total experiment package.

5. CREW SUPPORT

a. Functions:

(1) Experiment transfer from launch position and installation in spacecraft.

(2) Monitor condition of equipment.

(3) Ad hoc research activities. (Desirable to enhance scientific value and responsiveness of experiment, but not critical to successful execution of basic experiment.)

(a) Set up follow-on experiments with newly arrived experiment package.

(b) Ad hoc manual photography at request of P.I.

(c) Ad hoc TV monitoring at request of P.I.

(4) Experiment package preparation for logistics return.

b. Time - For each major research activity:

(1) set up 4 hrs

(2) Monitor system - 5 min/per day

(3) Experiment package preparation for return - 4 hrs.

c. Duty Cycle (requiring up to the suggested times depending on functions finally selected.)

(1) Assumptions:

(a) 3 experiment periods

(b) Duration: 21 days each.

(2) Set up: 4 hrs per event; 3 events

(3) Daily routine: 5 min. per day; 63 days.

(4) Experiment packaging: 4 hrs per event; 3 events

d. Skills: Technician.

See "Functions," paragraph 5.a

e. Special training: Training as technician with participating P.I's.

6. SPACECRAFT SUPPORT

a. Including Experiment Equipment for centrifuge and 0-g: Excludes weight of centrifuge, itself. Based on estimated 1 experiment container (holding 25 plants) at each of 2 acceleration levels, 0-g, and 1.0 g. Total of 2 units.

(1) Power: 50 watts continuous, no peak loads.

(2) Volume:

(a) Specimens, containers and expendables: 2 ft^3 (1 ft^3 per unit)

(b) Ancillary research equipment: nil.

(3) Weight:

(a) Specimens, containers and expendables: 50 lbs (25 lbs per unit).

(b) Ancillary research equipment: nil.

(4) Envelope:

(a) Specimens, containers and expendables: 2 units at 1 x 1 x 1 ft.

(b) Ancillary research equipment: Not applicable.

b. 0-g Experiment Equipment Only:

(1) Power: 25 watts continuous.

(2) Volume:

(a) Specimens, containers and expendables: 1 ft^3

(b) Ancillary research equipment: nil.

(3) Weight:

(a) Specimens, containers and expendables: 25 lbs.

(b) Ancillary research equipment: nil.

(4) Envelope:

(a) Specimens, containers and expendables: 1 x 1 x 1 ft.

(b) Ancillary research equipment: Not applicable.

c. Data:

(1) Continuous; dump each orbit:

(a) Accelerations in 6 d.f.: magnitude, duration and frequency.

(b) Vibrations in 6 d.f.; frequency amplitude and duration.

(c) Noise frequency, intensity and duration.

(d) Ambient radiation environment.

(2) Hourly record; dump daily:

(a) Temperature

(b) Relative humidity

(c) Gas composition and pressures; e.g. O_2, CO_2, N_2, CO etc.

(d) Illumination verification.

(e) Rate of rotation of centrifuge

(3) Dependent on design of experiment:

(a) Event acutation/termination verification

(b) Planned RF transmission of 1 35 mm. photograph each orbit.

(c) Automatic data and specimen reentry capsule - 1 per experiment.

(d) Specimen logistics return

(e) Photograph logistics return.

(4) Ad hoc - only occasional:

(a) Photograph transmission by RF.

(b) Real-time or near-real-time TV.

7. DEVELOPMENT SCHEDULE

Phase	A	B	C	D	Flight
FY	70	71	72	73-74	75

8. COST

Total: $1.35 M (excluding centrifuge).

FY	69	70	71	72	73	74	75
$ in Thousands	-	100	200	300	350	350	50

Phase	A	B	C	C	Data Reduction
$ in Thousands	100	200	300	700	50

EXPERIMENT DATA SHEET

DORSIVENTRALITY IN GAMETOPHYTES

1. SPECIFIC OBJECTIVE

Gametophytes will be studied to determine the effects of Earth gravity on metabolism, morphogenesis and fertilization when dorsiventrality is altered by long-term exposure to weightlessness. When grown on a clinostat, a condition somewhat analogous to weightlessness, morphological responses of the thalli are observable as marginal lobulation due to loss of dominance of the apical notch. Orbital flight will provide the means to observe the expected effects of true weightlessness on several metabolic functions during growth and development of the gametophyte. In turn, these studies will provide an ideal means to understand the basic role of gravity in the life of these plants leading to a clearer understanding of the basic phenomena of geotropism. This experiment can utilize a low-g centriguge to gain added information. However centrifugation is not a basic part of this experiment.

2. GENERAL DESCRIPTION

The organisms to be used are gemetophytes of Pteris longifolia grown in sealed modules. Approximately 200 spores will be inoculated in each module and grown under blue, green, yellow, red, and white light of equal light energy and intensity while in orbit. Specific characteristic changes under each light is expected, while under white light the effects of weightlessness will be observed while acting as flight controls against those grown under different lights.

The spores are non-responsive to vibration, g forces and acoustic stresses encountered during launch operation. The spores germinate 24 to 48 hours after inoculation; therefore, if launch takes place before germination the operational stresses will be insignificant.

Orbital flight for a period of 20 to 30 days should show morphological changes; when extended to 40 to 50 days, gemetangia formation should be observable; and after 50 to 60 days fertilization can be studied. Beyond 70 days and up to 250 days, early stages of sporophyte developmnet are expected. The sealed modules can maintain the organism readily up to 300 days. Some participation by a scientist astronaut would simplify the problem by in situ observation of growth anomalies, and modifications of protocol for follow-on experiments to elaborate on first results. Recovery stresses are minimized by the nature of the plant, permitting valid interpretation of the post-flight analyses.

Upon recovery, ultra-micro chemical, qualititive histochemical and cytochemical methods will be utilized to study the effect of weightlessness and relate the findings to geotropism. The data will be compared to the results obtained from our investigations on the clinostat and ground based centrifuge. After the experimental work is completed on the ground, then a comparative histo- and cytochemical analysis of the pre- and post-flight gametophyte will be made to enhance our knowledge of cellular metabolism by establishing enzymatic localization due to weightlessness.

3. OPERATIONAL CONSTRAINTS

Impact of the total launch and reentry environments upon test specimens must be minimized. Once in orbit, control of the acceleration

environment is desirable. Engineering solutions to minimize transient "station connected" g-forces must be achieved. A low g research centrifuge is desirable to increase scientific yield but is not critical to the success of a valid 0-g experiment. Periodic phenomena, vibration, and noise, unusual electromagnetic fields or other non-terrestrial phenomena should be quantified, recorded and minimized. Flight in an independent but dockable module may be required. During orbital flight altitude, inclination and pointing are not critical. However, during launch and reentry the direction of g-forces will be critical to avoid compromising the experiments or damaging the specimens.

4. MODE OF OPERATION

   a. Man attended and manipulated.

   b. If attached or integral: isolated from spacecraft acceleration. If detached: dockable for manned access and operations.

   c. Possibility of experiment repetition or modification, updating or replacement of equipment for advancement of research plans.

5. CREW SUPPORT

   a. Functions:

      (1) Laboratory housekeeping, maintenance and repair.

      (2) Experiment set up.

      (3) Monitor plants and condition of equipment.

      (4) Ad hoc research activities. (Desirable to enhance scientific value and responsiveness of experiment, but not critical to successful execution of basic experiment.)

(a) Set up follow-on experiments with:

(i) progeny of earlier on-board experimental plants.

(ii) newly arrived specimens.

(b) Common lab techniques e.g., fluid handling

(c) Gross morphological examination.

(d) Planned and _ad hoc_ photography

(e) _Ad hoc_ TV monitoring at request of ground based P.I.

(f) Collect and preserve whole specimens.

(5) Experiment termination.

(6) Experiment preparation for logistics return; package experiments, samples or photographs and other records for return to Earth.

b. Time - For each major research activity:

(1) Set up: 4 hrs.

(2) Laboratory housekeeping: 1/4 hr. once each 10 days

(3) Monitor equipment and plants: 1/4 hr per day

(4) Research procedures: up to 1 hr/per event.

c. Duty Cycle: (Requiring up to the suggested time depending on functions finally selected.)

(1) Assumptions:

(a) One extended experiment; several replicates.

(b) Duration: 300 days, maximum

(2) Setup: 4 hrs/event; 1 event.

(3) Daily routine: 5 min/day; 300 days.

(4) _Ad hoc_ research activities; 1 hr per event; 1 event per 10 days; Maximum: 30 events

(5) Termination and packing: 4 hrs. per event; 1 event

d. Skills: No professional skills necessary.

See "Functions," paragraph 5.a.

e. Special training: Minimal traning with participating P.I.'s

6. SPACECRAFT SUPPORT

a. Including Experiment Equipment for centrifuge and 0-g: Excludes weight of centrifuge itself. Based on estimated 2 units at each of 4 acceleration levels, 0-g to 1.0 g. Total of 8 units.

(1) Power: 48 watts (6 watts/unit) continuous, no peak load.

(2) Volume:

(a) Specimens, containers and expendables: 2.4 ft^3

(b) Ancillary research equipment: 0.5 ft^3.

(3) Weight:

(a) Specimens, containers and expendables: 56 lbs. (7 lbs/unit).

(b) Ancillary research equipment: 10 lbs.

(4) Envelope:

(a) Specimens, containers and expendables: 8 cylinders; each 8' diameter, 12" high.

(b) Ancillary research equipment: To be determined - not critical.

b. 0-g Experiment Equipment Only. Based on 2 unites at 0-g.

(1) Power: 12 watts (6 watts/unit) continuous

(2) Volume:

(a) Specimens, containers and expendables: $0.6 ft^3$ ($0.3 ft^3$/unit)

(b) Ancillary research equipment: $0.5 ft^3$

(3) Weight:

(a) Specimens, containers and expendables: 14 lbs (7 lbs/unit)

(b) Ancillary research equipment: 10 lbs

(4) Envelope:

(a) Specimens, containers and expendables: 2 cylinders; each 8' diameter x 12" high.

(b) Ancillary research equipment: To be determined - not critical

c. Data:

(1) Continuous; dump each orbit:

(a) Accelerations in 6 d.f.: magnitude, duration and frequency

(b) Vibrations in 6 d.f. frequency amplitude and duration.

(c) Noise frequency, intensity and duration.

(d) Ambient radiation environment.

(2) Frequent record; dump daily:

(a) Temperature: 6 per day

(b) Relative humidity: 6 per day

(c) Gas composition and pressures: e.g. O_2, CO_2, N_2, CO etc: 6 per day.

(d) Illumination verification: on/off, intensity: per day.

(e) Rate of rotation of centrifuge: 24 per day.

(3) Dependent on design of experiment:

(a) Event actuation/termination verification

(b) Specimen logistics return.

(c) Photograph logistics return.

(4) Ad hoc only occasional:

(a) Photograph transmission by RF.

(b) Real-time or near-real-time TV.

7. DEVELOPMENT SCHEDULE

Phase	A	B	C	D	Flight
FY	70	71	72	73-74	75

8. COST

Total: $0.725 M (excluding centrifuge)

FY	69	70	71	72	73	74	75
$ in Thousands	-	75	100	150	200	150	50

Phase	A	B	C	D	Data Reduction
$ in Thousands	75	100	150	350	50

EXPERIMENT DATA SHEET

THE ROLE OF AUXIN MEDIATED REACTIONS IN THE DEVELOPING WHEAT SEEDLING DURING WEIGHTLESSNESS

1. SPECIFIC OBJECTIVE

The primary objectives of this program are: (1) to determine the biochemical nature of the involvement of indoleacetic acid (IAA) in response of plants to weightlessness, and (2) to look for changes in nuclear material which are either responsible for the altered geotropic response, or caused by the altered geotropic response of the flight. The ultimate goal is an understanding of the biochemical and biophysical nature of plant responses to normal Earth gravity. An on-board centrifuge may increase the scientific yield of this work and is therefore desirable; if it is not available, the basic 0-g experiment will be carried out.

2. GENERAL DESCRIPTION

The mechanism of auxin action is quite complex. It appears that indirect methods of approach might help to clarify some aspects of the problem.

Auxin Biochemistry: The auxin - antiauzin biochemical interraction, for example, is one way in which the mechanism can be effectively studied. Through the addition of an applied stimulator (auxin) or inhibitor (anti-auxin) one can then measure its influence, if any, upon metabolism and energetics. Several enzyme systems in a metabolic pathway can be assayed simultaneously when radioactive tracers are used.

The pathways of glucose metabolism, for example, can be measured in this manner by incubating the tissue with IAA (for one of the anti-auxins), together with uniformly labeled C^{14} - glucose, and assaying the radioactivity of metabolites. By comparing the results from tissues grown in Earth orbit with Earth clinostat and erect controls, and correlating these data with the extent of curvature of plant structure, the interrelationships should become more clear. Similar studies performed on the several pathways of metabolism and energetics would then lead to a better understanding of the influence of the hormone upon the geotropic response.

Similarly, it would be relatively simple to judge the effects of peroxidase upon IAA activity and thereby end another controversy. Incubating carboxyl labeled IAA-C^{14} with homogenate from Earth orbit, clinostat, and erect grown coleoptiles should result in a decrease in radioactivity in the reaction milieu, if as expected, this enzyme enhances the hydrolysis of the terminal carboxyl group. Confirmatory evidence would easily be obtained by suing methylene tagged, or ring tagged, indole - 3 - acetic acid and noting the difference in radioactivity. If peroxidase does indeed influence auxin concentration and effectiveness, there should be decrease in radioactivity.

Space Nucleic Acid Biochemistry: One hypothesis advanced previously by the writer which could explain the multitude of responses of the different forms of life to weightlessness, or weightlessness-radiation interaction, is the masking of DNA by the nucleohistone. When the histone covers the DNA molecule, it interferes with the RNA synthesis by blocking RNA polymerase. The protective mechanism against radiation damage

has already been demonstrated. If the histone removal was retarded during weightlessness, any number of biological interferences could rise. The differences in the reaction of the different species could be attributed to the site on the DNA molecule which was covered by the histone.

In order to examine this hypothesis more critically, it is suggested that the folowing experiments be conducted;

a. Isotope Incorporation Study

Isotope incorporation into germinating wheat seeds can be accomplished through soaking in tritiated water. The seeds would be divided for growth in weightlessness on the horizontal clinostat and suitable controls. The relative amount of radioactivity in extracted DNA, RNA and nuclechistone will be indicative of some of the biological processes in question. Similar studies measuring C^{14} separately and in combination with H^3 will provide additional insight into the problem.

b. Nucleoside Triphosphate Incorporation into RNA

Since the effect of masking DNA by the histone is to retard the activity of RNA polymerase, the effect of growth in weightlessness upon the histone DNA interaction can be determined. Comparing the rate of radioactive tagged nucleoside triphosphate incorporated into RNA with chromatin isolated from seedlings grown (1) in Earth orbit, (2) on a horizontal clinostat and (3) in control seedlings as the template will then provide a means of confirming or refuting this hypotheses.

Only through additional studies such as those proposed above can the biochemical changes in the developing plant in the weightless state be clearly resolved and the phenomenon of geotropism understood.

3. OPERATIONAL CONSTRAINTS

Impact of the total launch and reentry environments upon test specimens must be minimized. Once in orbit, control of the acceleration environment is desriable. Engineering solutions to minimize transient "station connected" g-forces must be achieved. A research centrifuge is desirable to enhance sceintific returns, but is not critical to the success of a valid 0-g experiment. Periodic phenomena, vibration and noise, unusual electromagnetic fields or other non-terrestrial phenomena should be quantified, recorded and minimized. Flight on an independent but dockable module may be required. During orbital flight altitude, inclination and pointing are not critical; however during launch and reentry, depending on nature of test organisms, direction of g-forces may be critical.

4. MODE OF OPERATION

a. Man attended and manipulated.

b. If attached or integral: isolated from spacecraft acceleration

If detached: Dockable for manned access and operations.

c. Possibility of experiment repetition or modification, and a reuse, updating or replacement of equipment for advancement in research plans.

5. CREW SUPPORT

a. Functions:

(1) Laboratory housekeeping, maintenance and repair.

(2) Experiment set up.

(3) Monitor plants and condition of equipment.

(4) Ad hoc research activities. (Desirable to enhance scientific value and responsiveness of experiment, but not critical to successful execution of basic experiment.)

(a) Set up follow-on experiments with:

(i) Tissue from prior experiments.

(ii) on board seed stocks.

(iii) newly arrived seeds.

(b) Common lab techniques, e.g. mass measurement, fluid handling.

(c) Gross morphological examination.

(d) Ad hoc photography at request of P.I.

(e) Ad hoc TV monitoring in conference with P.I.

(f) Install and operate plant physiological and metabolic instrumentation, etc.

(g) "Dry" or "Moist" chemistry for qualitative and semi-quantitative tests.

(h) Radiobiology techniques - isotopic tracers - administer and detect.

(i) Collect and preserve whole specimens.

(j) Dissect and freeze specimens:(Ambient Dry ice LN_2)

(5) Experiment termination

(6) Specimen proparation for logistics return; package experiments, samples photographs and other record for return to Earth.

b. Time - For each major research protocol:

(1) Set-up: 8 hrs.

(2) Laboratory housekeeping: 1/4 hr per day.

(3) Monitor equipment and plants: 1/4 hr per day.

(4) Research procedures: up to 4 hrs per event.

(5) Termination: preserve, pack for return - 8 hrs.

c. Duty Cycle: (Requiring up to the suggested time depending on functions finally selected.)

(1) Assumptions:

(a) Three experiments in series.

(b) Duration of each: 21 days

(2) Setup: 8 hrs/event; 3 events.

(3) Daily routine: 1/2 hr/day; 63 days.

(4) Ad hoc research activities: 4 hrs. per event; 4 events per experiment; 3 experiments.

(5) Termination and packing: 8 hrs. per event; 3 events.

d. Skills: Professional plant physiologist or gifted technical assistant. See "Functions," paragraph 5.a.

e. Special training: Training as research associate with participating P.I.'s.

6. SPACECRAFT SUPPORT

a. Including Experiment Equipment for Centrifuge and 0-g: Excludes weight of centrifuge. Based on estimated 4 reuseable, modified Biosatellite wheat seedling growth units (12 seeds each), at each of 6 acceleration levels, 0-g, 0.2 g, 0.4 g, 0.6 g, 0.8 g, and 1.0 g. Total 24 units.

(1) Power - 100 watts continuous.

(2) Volume:

(a) Specimens, containers and expendables: 6.0 ft^3 (0.25 ft^3 per unit).

(b) Ancillary research equipment: 0.5 ft^3

(3) Weight:

(a) Specimens, containers and expendables: 48 lbs. (2.0 lb per unit).

(b) Ancillary research equipment: 10 lbs.

(4) Envelope:

(a) Specimens, containers and expendables: 24 containers, each 6 x 6 x 12 in. high.

(b) Ancillary research equipment: To be determined not critical.

b. 0-g Experiment Equipment only:

Based on 4 units at 0 g.

(1) Power: 16 watts continuous (ca 4 watts per unit)

(2) Volume:

(a) Specimens, containers, and expendables: 1 ft^3 (0.25 ft^3 per unit)

(b) Ancillary research equipment: 0.5 ft^3

(3) Weight:

(a) Specimens, containers and exeendables: 8 lb (2.0 lb per unit)

(b) Ancillary research equipment: 10 lb.

(4) Envelope:

(a) Specimens, containers and expendables: 4 containers each 6 x 6 x 12 inches

(b) Ancillary research equipment: To be determined - not critical

c. Data:

(1) Continuous; dump each orbit:

(a) Accelerations in 6 d.f.: magnitude, duration and frequency.

(b) Vibrations in 6 d.f.; frequency amplitude and duration

(c) Noise, frequency intensity and duration.

(d) Ambient radiation environment.

(2) Hourly record; dump daily:

(a) Temperature

(b) Relative humidity

(c) Gas composition and pressures: e.g. O_2, CO_2, N_2, CO etc.

(d) Illumination verification: on/off, periodicity, intensity.

(e) Rate of rotation of centrifuge

(3) Dependent on desing of experiment:

(a) Event actuation/termination verification

(b) Radiation intensity data from planned experiments

(c) Automatic data and specimen reentry capsule. 1 per experiment.

(d) Specimen logistics return.

(e) Photograph logistics return.

(4) Ad hoc - only occasional:

(a) Photograph transmission by RF.

(b) Real-time or near-real-time TV.

(c) Emergency radiation intensity data.

7. DEVELOPMENT SCHEDULE

Phase	A	B	C	D	Flight
FY	70	71	72	73-74	75

8. COST

Total $1.35 M (excluding centrifuge)

FY	69	70	71	72	73	74	75
$ in Thousnads	-	50	100	250	500	400	50

Phase	A	B	C	D	Data Reduction
$ in Thousands	50	100	250	900	50

EXPERIMENT DATA SHEET

ROLE OF GRAVITATIONAL STRESS IN LAND PLANT EVOLUTION:

THE GRAVITATIONAL FACTOR IN LIGNIFICATION.

1. SPECIFIC OBJECTIVE

Study the extent and pattern of lignification in suitable test plants grown from seed during extended Earth orbital flight. The plant response, whatever may be its direction will demonstrate decisively whether or not a g-value of the order of magnitude of the terrestrial normal value is required for the lignification process. Understanding of the role of gravity in lignin formation provides a key to the past history and present physiology of woody plants. This experiment could benefit from on-board centrifuge to provide 1-g controls. If not available, the basis 0-g experiment will be carried out.

2. GENERAL DESCRIPTION

It has been known that gravity does indeed play a role, but space flight has for the first time provided a completely unconfounded experiment environment in which to study this phenomenon.

The basic experiment will require the placement of anchored trays or flats containing a suitable substratum, water, and presoaked seeds of cucumber. Alternatively, hydration of pre-planted dry seeds can be the duty of an on-board scientist or technician to avert launch effects on sprouting seeds. Trays or flats will be loosely covered initially with thin films of polyethylene or similar plastic materials; or, if water conservation constitutes a problem, trays may be enclosed in

large plastic bags. Little or no care of these seedlings during their subsequent growth is anticipated and, upon termination of the mission, the material would be recovered for histological and biochemical examination would entail study of fibrovascular tissues, extravascular mechanical tissues, and epidermis. Cytology would concentrate upon wall structure including optical and electron microscopy. Biochemical examination would include fractionation and analysis for lignin and all other major wall constituents.

This basic plan will bw supplemented, if feasible, by the following in-flight experiments:

a. Cucumber seedlings will be grown from seed under artificially induced gravitation with an on-board centrifuge; this experiment will provide a control for general orbital conditions. These would be handled post-flight in the same manner as would be the plants in the basic experiment.

b. Two-week-old cucumber seedlings will be severed from their roots, and the cut stumps maintained in aqueous solution; as soon as orbital status is obtained, upright rootless stems which have been placed with lower end in buffered aqueous medium will be supplied with radioactive coniferal alcohol. No maintenance problem is foreseen. After recovery, the location of radioactivity in the plant body, its tissues, and ceels would be determined by chemical fractionation and counting procedures.

The successful demonstration of a change in lignification under the influence of altered gravitational stress would be followed by a study of the physico-chemical factors that might underlie an altered pattern of lignin deposition. These include the perosidase enzymes, the various H_2O_2 - generating flavopooteins, the presence of aromatic lignin precursors and the composition of the wall itself.

Suitable ground-based control and supplementary experiments will be carried out.

Cucumber has been chosen for this study because they are capable of rapid growth and vascular development during periods of 10 days to two weeks while retaining herbaceios character. Theri lignin content is low, on the average, but is highly concentrated in fibrovascular and mechanical tissues which are therefore more readily examined against an unlignified tieeue background. Unlike woody tissues which may run 35-40% lignin, these plants normally contain approximately 4-7% lignin in their stems, and less in other organs. However, the lack of interfering substances makes these plants amenable to total extraction by acid solvolysis and to direct colorimetry. If gravitational stress is of major significance in lignification, then the lignin content of plants grown during an orbital mission could approach a zero value.

Biochemical studies will be supplemented by histological, morphological and ultrastructural studies of cell walls and their constituents. Arrangement of wall components will also include the use of polarized flight analysis to determine optical axes of cell wall microfibrillae.

3. OPERATIONAL CONSTRAINTS

Impact of the total launch and reentry environments upon test specimens must be minimized. Once in orbit control of the acceleration environment is desirable. Engineering solutions to minimize transient "station connected" g-forces msut be achieved. A research centrifuge is desirable to maximize scientific return, but is not critical to the success of a valid 0-g experiment. Periodic phenomena, vibration and noise, unusual electromagnetic fields or other non-terrestrial phenomena should be quantified, recorded and minimized. Flight on an independent but dockable module may be required. During orbital flight altitude, inclination and pointing are not critical; however, during launch and reentry, depending on test specimens, direction of g-forces may be critical.

4. MODE OF OPERATION

a. Man attended and manipulated.

b. If attached or integral: Isolated from spacecraft acceleration.

   If detached: Dockable for manned access and operations.

c. Possibility of experiment repetition or modification, and reuse, updating or replacement of equipment for advancement of research plans.

5. CREW SUPPORT

a. Functions:

   (1) Laboratory housekeeping, maintenance and repair

   (2) Experiment set up.

   (3) Monitor condition of plants and equipment.

(4) Ad hoc research activities. (Desirable to enhance scientific value and responsiveness of experiment, but not critical to successful execution of basic experiment.)

(a) Set up follow-on experiments with:

(i) on-board seed stocks

(ii) newly arrived seeds or seedlings.

(b) Common lab techniques e.g. mass measurement, fluid handling.

(c) Gross morphological examination.

(d) Ad hoc photography at request of P.I.

(e) Ad hoc TV monitoring in conference with ground P.I.

(f) Install and operate plant physiological and metabolic instrumentation, etc.

(g) "Dry" or "Moist" chemistry for qualitative and semi-quantitative tests.

(h) Radiobiology techniques - isotopic tracers - administer and detect.

(i) Collect and freeze whole specimens.

(j) Dessect and preserve specimens

(k) Isolate, freeze tissues

(5) Experiment termination.

(6) Specimen preparation for logistics return; package experiments, samples, photographs and other records for return to Earth.

b. Time - For each major research activity of the classes below:

(1) Set up: 8 hrs.

(2) Laboratory housekeeping: 1/4 hr/day.

(3) Monitor equipment and plants: 1/4 hr/day

(4) Research procedures: up to 4 hrs. per event.

(5) Termination: dissect, preserve, pack for return - 8 hrs.

c. Duty Cycle: (Requiring up to the suggested time depending on functions finally selected.)

(1) Assumptions:

(a) 3 experiments in series.

(b) Duration of each: 21 days.

(2) Setup: 8 hrs/event; 3 events.

(3) Daily routine: 1/2 hr/day; 63 days.

(4) <u>Ad hoc</u> research activities: 4 hrs. per event; 2 events per week; 9 weeks.

(5) Termination and packing: 8 hrs. per event; 3 events.

d. Skills: Professional physiologist or gifted technical assistant. See "Functions," paragraph 5.a.

e. Special training: Training as research associate with participating P.I.'s.

6. SPACECRAFT SUPPORT

a. Including Experiment Equipment for Centrifuge and 0-g: Excludes weight of centrifuge. Based on estimated 1 unit at each of 2 acceleration levels, 0-g and 1.0 g. Total of 2 units.

(1) Power - 100 watts continuous (50 watts per unit).

(2) Volume:

(a) Specimens, containers and expandables: 1 ft^3 (0.5 ft^3 per unit)

(b) Ancillary research equipment: 0.5 ft^3

(3) Weight:

(a) Specimens, containers and expandables: 20 lbs (10 lbs per unit)

(b) Ancillary research equipment: 10 lbs.

(4) Envelope:

(a) Specimens, containers and expandables: 2 units each 0.5 x 1 x 1 ft.

(b) Ancillary research equipment: To be determined - not critical.

b. 0-g Experiment Equipment only:

Based on 1 unit at 0-g.

(1) Power: 50 watts continuous

(2) Volume:

(a) Specimens, containers and expandables: 0.5 ft^3

(b) Ancillary research equipment: 0.5 ft^3

(3) Weight:

(a) Specimens, containers and expandables: 10 lbs.

(b) Ancillary research equipment: 10 lbs.

(4) Envelope

(a) Specimens, containers and expandables: 1 unit 0.5 x 1 x 1 ft.

(b) Ancillary research equipment: To be determined -- not critical.

c. Data:

(1) Continuous; dump each orbit:

(a) Accelerations in 6 d.f.: magnitude, duration and frequency

(b) Vibration in 6 d.f.; frequency, amplitude and duration

(c) Noise frequency, intensity and duration

(d) Ambient radiation environment.

(2) Hourly record; dump daily:

(a) Temperature

(b) Relative humidity

(c) Gas composition and pressures: e.g. O_2, CO_2, N_2, CO etc.

(d) Illumination verification: on/off, periodicity, intensity

(e) Rate of rotaiton of centrifuge

(3) Dependent on design of experiment:

(a) Event actuation/termination verification

(b) Radiation intensity data from planned experiments

(c) Automatic data and specimen reentry capsule. 1 per experiment.

(d) Specimen logistics return

(e) Photograph logistics return.

(4) <u>Ad hoc</u> - only occasional:

(a) Photograph transmission by RF.

(b) Real-time or near-real-time TV.

(c) Emergency radiation intensity data.

7. DEVELOPMENT SCHEDULE

Phase	A	B	C	D	Flight
FY	70	71	72	73-74	75

8. COST

Total: $1.8 M (excluding centrifuge)

FY	69	70	71	72	73	74	75
$ in Thousands	-	100	200	400	600	450	50

Phase	A	B	C	D	Data Reduction
$ in Thousands	100	200	400	1050	50

EXPERIMENT DATA SHEET

EFFECT OF GEOPHYSICAL FACTORS ON CIRCADIAN RHYTHMS IN PLANTS

---Studies on the Circadian Leaf Movements of Pinto Beans

---Environmental Factors Regulating Circadian Rhythms in Phaseolus Leaves

1. SPECIFIC OBJECTIVE

The objective of these experiments is to determine the effect, if any, of the Earth Orbital environment upon the circadian leaf movements of the pinto bean when (a) constant conditions or (b) an arbitrary light/dark cycle is imposed and (c) when the light/dark cycle is regulated by the plant itself. An on-board centrifuge may be sueful for certain aspects of this research. If it is not available the basic 0-g experiment will be carried out.

2. GENERAL DESCRIPTION

In plants, the circadian leaf movement has been extensively studies and can be monitored for extended periods under uniform conditions. In Phaseolus plants the leaf blade moves to a horizontal position during the day and then slowly swings down to a vertical position at night. These rhythmic movements are repeated each day. This rhythm in leaf movement can be easily monitored through use of either photography or electronic strain gauges (6). Changes in the rhythm can be analyzed quantitatively in terms of amplitude and period length of the leaf movements.

Bean plants exhibit a persistent circadian leaf movement under continuous fluorescent light that can be maintained for as long as 28 days (3). For this reason, this experiment could be adapted to a 30 day investigation. This movement is persistent under light levels as low as 100 foot candles intensity of fluorescent light.

The experiment will consist of twelve plants housed in groups of six in two identical packages. The function of the package will be to photograph the bean plants in two distinct illumination environments and provide life support for the biology. During the first 168 hours one of the packages will alternately expose the plants to 12 hours of light at 200 foot candles, and 12 hours of dark. The plants will be exposed to 200 foot-candles of con tinuous light after the period of cycling. The second package will expose the plants to 200 foot-candles of continuous light throughout the experiment period. Photography furing the dark cycle will be accomplished by utilizing the synchronized lighting of the existing light system or an alternate system, such as infrared.

It is also proposed to include a group of plants on operating in a dynamic feedback mode. In these experiments, the plants control their own light regime. In most of the rhythm studies the constant conditions imposed on the plants do not constitute a natural situation. If, on the other hand, the experimental plant is exposed to a more natural light and dark cycle, the rhythm which is to be investigated tends to be entrained by the light-dark cycle imposed on it and is therefore not "free running." Due to this inherent difficulty, constant constant conditions have been used to study "free running" plant rhythms. To overcome this difficulty we have developed a light control system in which lights are turned off and on by the leaf movements of the plants, thereby enabling each individual plant to regulate the photoperiodic condition to which it is exposed. By this means the orbital experiments will include for the first time a truly free-running plant. Previous experience in ground experiments suggest that the feedback plants will have a significantly different rhythm from those exposed to the usual constant light condtions.

3. OPERATIONAL CONSTRAINTS

Impact of the total launch and reentry environments upon test specimens must be minimized. Once in orbit, control of the acceleration environment is critical. Engineering solutions to minimize transient "stati n connected" forces must be achieved. Flgint in an independent, dockable module may be required. The plants must be isolated from any periodic phenomena and from noise, unusual electromagnetic fields or other non-terrestrial phenomena. During orbital flight, altitude, inclination and pointing are not critical. It is expected that this experiment will be conducted without using the on-board centrifuge.

4. MODE OF OPERATION

a. Man attended and manipulated.

b. If attached or integral: isolated from spacecraft acceleration. If detached: dockable for manned access and operations.

c. Possibility of experiment repetition or modification, and reuse, updating or replacement of equipment for advancement in research plans.

5. CREW SUPPORT

a. Functions:

(1) Laboratory housekeeping, maintenance and repair.

(2) Experiment set up.

(3) Monitor plants and condition of equipment.

(4) Ad hoc research activities. (Desirable to enhance scientific value and responsiveness of experiment, but not critical to successful execution of basic experiment.)

(a) Set up follow on experiments with:

(i) plants grown on board from seed

(ii) Plants sent up on logistics flight.

(b) Common lab techniques, e.g., mass measurement, fluid handling, media preparation.

(c) Gross morphological examination.

(d) Planned and _ad hoc_ photography.

(e) _Ad hoc_ TV monitoring in conference with ground P.I.

(f) Install and operate plant physiologocal instrumentation, etc.

(g) Collect and preserve whole specimens.

(h) Dissect and preserve specimens.

(5) Experiment termination.

(6) Specimen preparation for logistics return; package, experiments, samples photographs and other records for return to Earth.

b. Time - For each major research activity of the classes below:

(1) Set up: 8 hrs.

(2) Laboratory housekeeping: 1/4 hr. per day.

(3) Monitor equipment and plants including watering and pruning: 1/4 hr. per day.

(4) Research procedures: up to 2 hrs. per event.

(5) Termination: sacrifice, dissect, preserve, pack for return - 8 hrs.

c. Duty Cycle: (Requiring up to the suggested time depending on functions finally selected).

(1) Assumptions:

(a) Three experiments in series.

(b) Duration of each: 30 days.

(2) Setup: 8 hrs/event; 3 events.

(3) Daily routine: 1/2 hr/day; 90 days.

(4) Ad hoc research activities: 2 hrs. per event; 2 events per week; 12 weeks.

(5) Termination and packing: 8 hrs. per event; e events.

d. Skills: Professional plant physiologist of gifted technical assistant, especially including photographic skill.

See "Functions," paragraph 5.a.

e. Special training: Training as research associate with participating P.I.'s.

6. SPACECRAFT SUPPORT

a. Including Experiment Equipment for Centrifuge and 0-g:

Centrifuge not employed. Section not applicable.

b. 0-g Experiment Equipment only:

Based on estimated 1 unit containing 12 plants.

Total of 1 unit.

(1) Power - 50 watts continuous, 250 watts during peak lighting loads.

(2) Volume:

(a) Specimens, containers and expendables: 2 ft^3

(b) Ancillary research equipment: 0.5 ft^3

(3) Weight:

(a) Specimens, containers and expendables: 15.0 lbs.

(b) Ancillary research equipment: 10 lbs.

(4) Envelope:

(a) Specimens, containers and expendables: Box 2 x 1 x 1 ft.

(b) Ancillary research equipment. To be determined - not critical

c. Data:

(1) Continuous; dump each orbit:

(a) Accelerations in 6 d.f.: magnitude, duration and frequency

(b) Vibrations in 6 d.f.: frequency, amplitude and duration

(c) Ambient radiation environment

(d) Noise crew activity spacecraft operations which could prove to be rhythmic.

(e) Leaf bending activity (strain gauges).

(2) Randomly record; 24 per day; dump daily:

(a) Temperature

(b) Relative humidity

(c) Gas composition and pressures: e.g. O_2, CO_2, N_2, CO etc.

(d) Illumination verification: on/off, periodicity, intensity.

(e) Rate of rotation of centrifuge

(3) Dependent on design of experiment:

(a) Event actuation/termination verification

(b) Specimen logistics return

(c) Photograph logistics return.

(4) <u>Ad hoc</u> - only occasional:

(a) Photograph transmission by RF.

(b) Real-time or near-real-time TV.

7. DEVELOPMENT SCHEDULE

Phase	A	B	C	D	Flight
FY	70	71	72	73-74	75

8. COST

Total $1.4 M (centrifuge not used)

FY	69	70	71	72	73	74	75
$ in Thousands	-	100	200	300	450	300	50

Phase	A	B	C	D	Data Reduction
$ in Thousands	100	200	300	750	50

FUNCTIONAL PROGRAM ELEMENT V

INVERTEBRATES (BIO F)

1. RELATED DISCIPLINE - Space Biology (Bioscience)

2. PROGRAM ELEMENT - Invertebrates (Bio F)

3. REQUIREMENT

Extend the survey and in-depth study of the role of gravity in the normal and abnormal invertebrate animals by studying their responses to weightlessness, evolving from the results gained in the Biosatellite Program toward plans for research in the Biotechnology Lab.

4. JUSTIFICATION

a. The biological scientific community has identified a need for these data arising from both survey and in-depth experimentation.

b. The manned space flight and bioscience communities have endorsed this activity (FPE Bio F) as a means for evolving a flexible, responsive, and powerful mode of carrying out research on the above test subjects in the Biotechnology Lab.

c. The capability of long-term space systems to meet the environmental needs and the spacecraft support requirements must be evaluated in the operational environment, e.g., (1) provision of a very low acceleration environment; (2) isolation of invertebrate animal experiments from rhythmic or cyclic phenomena.

d. The ability of man to monitor, maintain and repair experiments and equipment must be demonstrated operationally. The capability of the scientist/crewman must also be tested to determine whether he can (1) receive test invertebrate animals, eggs, larvae pupae or other material, (2) perform in-flight

experimental preparation of animals for (3) installation in on-board work stations or independent flight experiment modules, (4) make direct observation or recordings on the test subjects, (5) perform various specimen collection and preservation techniques including biopsy, body fluid sampling, sacrifice, autopsy and serendipitous or ad hoc demand observations, (7) modify experiment protocol and conditions and (8) terminate animal experiments preparing both live specimens and preserved material for logistics return. The requirement for, and role of an invertebrate physiology/morphology specialist in a space station must be determined in operational tests.

e. Technological requirements must be satisfied: (1) for the evolution of invertebrate research equipment for incorporation in the Biotechnology Lab; and (2) in the area of providing a low-g research environment free of rhythmic "cue" phenomena.

5. COMPONENT EXPERIMENTS

The experiment selections and descriptions given herein are only typical. They are in no way intended to indicate the final selections or formats. They are given here only to permit planners to assess the impact of a typical animal research Functional Program Element on the total space flight system. The experiments comprising Bio F are grouped in seven areas characterized either by (1) potential for common use of same test individuals by a number of principal investigators, (2) unique importance of the biological area of interest or (3) unique environmental conditions required by the test subjects:

a. The role of gravity in the function of the invertebrate organism throughout its life cycle.

(1) The effects of weightlessness on the life cycle

phenomena in Drosophila.

(2) The effects of weightlessness on reproduction in Drosophila

b. The role of gravity in morphogenesis in invertebrates.

(1) The effects of the space environment on embryogenesis and development in beetles.

(2) The effects of the space environment on morphogenesis in non-Holometabolous insects.

c. The role of gravity in invertebrate metabolism.

(1) The effects of the space environment on invertebrate cellular metabolism.

d. The role of gravity in aging in invertebrates.

(1) The effects of weightlessness on general age-related functions in insects.

(2) The effects the space environment on cellular level phenomena and aging in insects.

e. The role of gravity in genetics phenomena in invertebrates.

(1) The effects of hypogravity on mutability in adult Drosophila.

(2) The effect of weightlessness on chromosomal rejoining.

(3) Resistance to the genetic effects of weightlessness afforded by genetic diversity.

(4) The effects of hypogravity in producing specific cytologically identifiable anomalies in chromosomes.

f. Biorhythmicity in invertebrates.

(1) Circadian rhythms in Drosophila during orbital flight.

(2) Circadian rhythms in cockroaches during orbital flight.

(3) Biorhymicity of fiddler crab activity and respiration in orbital flight.

g. The role of gravity in influencing behavior in invertebrates.

(1) Discrimination and communication in bees during long term exposure to weightlessness.

(2) Orientation and geosensing in spiders.

6. DESCRIPTION

Bio F is a cluster of invertebrate animal experiment modules grouped together on the basis of commonality in: equipment requirements, support requirements, research approaches, and specimen handling and observation techniques.

a. Approximate Characteristics (Typical)

Weight: 325 lbs.

Volume: 18 ft. ^{3}

Power: 300 lbs.

Cost: Costs Include Experiment Development Costs Only $16.05M

b. Variable packaging geometry can be used.

c. Envelope is undefined. FPE Bio F can be deployed in a workstation developed for Bio D or in an independent module developed for Bio E.

d. Individual experiment developments are independent of the development of both the space station and Bio F program element.

7. SPECIAL CONSIDERATIONS

a. Minimization of acceleration, vibration and noise in magnitude (or intensity), duration, and frequency of exposure (6 d.f)* is required.

b. Continuous record of accelerations (6 d.f.) vibrations and noise is required. (See 7 a.)

c. Isolation from all periodic or rhythmic phenomena (vibration, noise, thermal, etc.) is required.

*Footnote: 6 degrees of freedom of acceleration; 3 translation plus 3 rotational.

e. Multipurpose photographic capability required for both microscopic and macroscopic objects in both planned and ad hoc research operations.

f. Real-time TV or near-real-time video tape capability desirable ad hoc observation by ground based P.I. of experiment equipment, procedures, and both microscopic and macroscopic specimens.

g. The animal facility will require an environmental control system isolated from the spacecraft system to permit removal of specimens from their housing for transfer, research procedures or logistics preparation.

h. Scientist-astronaut work space for manipulation of experiments, ancillary equipment and specimens must be provided as a part of the FPE. Capability to pressurize the workspace to sea level atmospheric conditions must be provided if on-board scientist is to manipulate specimens in the workspace outside of their containers. Appropriate operational doctrine to permit scientist to do useful work during his decompression periods must be developed.

i. The animal facility will be either internal to the space station or permanently docked.

j. A data handling system common within the Functional Program Element would be desirable to link the experiment sensors through the FPE, through the space station Data Management Sustem to Earth.

k. A common use specimen preservation system would be desirable for freezing or freeze-drying specimens for return to Earth at the usual logistics intervals.

l. Automatic reentry capsules will be desired for return of specimens, photographs, records, or total experiment packages.

EXPERIMENT DATA SHEET

THE ROLE OF GRAVITY IN THE FUNCTION OF THE INVERTEBRATE ORGANISM THROUGHOUT ITS LIFE CYCLE

---The effects of weightlessness on life cycle phenomena in Drosophila.

---The effect of weightlessness on reproduction in Drosophila.

1. SPECIFIC OBJECTIVES

The goal of these experiments is to observe the gross effects of long term exposure of invertebrates to weightlessness upon basic life phenomena such as longevity, metabolism, behavior, reproduction, and development.

2. GENERAL DESCRIPTION

Newly emerged adults or pupae emerging in orbit would be used as one test animal for general studies. Other tests would be run on insects hatched from eggs in orbit. Photographic records will provide information on the developmental cycle, e.g. duration of instars, pupation time, longevity of adults. Specimens killed at appropriate times will give an opportunity to detect any abnormalities of development or function, by on board, or post flight examination. Activity level and other aspects of behavior can be detected by monitoring metabolic gas levels and by audiovisual recordings. Analysis of growth media will yield data on metabolism during flight.

Photographic records taken of mating behavior can be analyzed post flight to detect anomalies. Fecundity and fertility records based on egg deposition and egg batch can be likewise recorded. Embryonic and post embryonic development of individuals from eggs fertilized in space

can be followed during flight. Photographic records and specimens fixed at suitable times can be examined on board and post flight for morphogenetic anomalies.

3. <u>OPERATIONAL CONSTRAINTS</u> - Acceleration environment is critical. Engineering solutions to minimize force can be achieved. Altitude, inclination, pointing not critical. Must be isolated from any periodical phenomena.

4. <u>MODE OF OPERATION</u> -

   A. Man attended

   B. If attached: isolated from S/C acceleration.
      If detached: dockable for man access.

   C. Continuous operation.

5. <u>CREW SUPPORT</u>

   A. Functions: Set up experiment; monitor; maintain and repair; operate photomicrographic system; manipulate eggs, larvae, pupae and adults for subculture of experiments; simple biochemical analysis; sample preservation for return; experiment termination.

   B. Time: Experiment set up: 1 hr. per experiment
      Experiment operations: 2 hrs. per experiment per day
      Experiment termination: 2 hrs. per experiment

   C. Duty cycle: Once per day; 90 days; number of simultaneous experiments to be determined.

   D. Skills: See 5A

   E. Special training: Equivalent to laboratory assistant, plus *ad hoc* training with P. I.

6. SPACECRAFT SUPPORT

A.	Power	50 watts max
B.	Volume	2 ft^3
C.	Weight	25 lbs.
D.	Envelope	TBD
E.	Data	Film specimens and records to be recovered; total S/C environment including accelerations.

7. DEVELOPMENT SCHEDULE

Phase A	Phase B	Phase C	Phase D
FY '70	FY '71	FY '72	FY '73-'74

8. COST-COSTS INCLUDE ONLY EXPERIMENT DEVELOPMENT

Total $2.1 M

FY '70	FY '71	FY '72	FY '73	FY '74	Flight
$200 K	$200 K	$400 D	$600 K	$600 K	$100 K

B190

EXPERIMENT DATA SHEET

THE ROLE OF GRAVITY IN MORPHOGENESIS IN INVERTEBRATES

---The effects of the space environment on embryogenesis and development in insects.

---The effects of the space environment on morphogenesis in non-Holometabolous insects.

1. SPECIFIC OBJECTIVES

The specifice goals of this group of experiments is to define more closely the nature of morphogenetic anomalies found in earlier space flight and to determine the underlying mechanisms.

2. GENERAL DESCRIPTION

Certain phases of embryonic and pupal development of common beetles are known to be sensitive to changes in a number of environmental factors. Eggs and pupae of Tribolium and Tenebrio will be exposed to weightlessness during the sensitive period. By comparison with a suitable battery of control insects, specific morphogenetic abnormalities will be identified, including ~~and~~ in addition to those found in an earlier Biosatellite flight. By broadening the scope of species investigated it should be possible to assess the general morphogenetic implications of data obtained thus far in space. On board observations and film records will make possible the detection of any alteration in timing of morphogenetic events. The onboard investigator will fix specimens at pre-set intervals in order to detect early stages of morphogenetic abnormalities before they become frankly expressed. Once abnormalities are detected, the specimen can be removed and preserved at the option of the P.I. in order to maximize the information yield from the specimen. Judicious cooperation between the onboard investigator and the P.I. can produce a complete series of specimens from which the course of abnormal development can be followed in detail.

~~4~~ 8

In similiar fashion the interaction of weightlessness with other known factors producing abnormalities can be studied in detail.

Simultaneous studies using standard laboratory species representing the other classic divisions of Insects, i.e. the Paurometabola and Semimetabola, should be carried on. Each has periods of morphogenetic sensitivity to external environmental factors. Cross-comparisons of results with all metabolic forms could increase understanding of both the morphogenetic process as a whole and the anomalies seen in weightlessness.

3. OPERATIONAL CONSTRAINTS

Acceleration environment is critical. Engineering solutions to minimize force can be achieved. Altitude, Inclination, pointing not critical. Must be isolated from any periodical phenomena.

4. MODE OF OPERATION

A. Man attended

B. If attached: isolated from S/C acceleration
   If detached: dockable for man access

C. Continuous operation.

5. CREW SUPPORT

A.	Functions:	Initiate experiment; monitor; maintain and repair; photograph specimens; specimen handling; specimen preservation and preparation for return; experiment termination.
B.	Time:	Experiment set up: 1 hour per experiment Experiment Operations: 2 hours per day, per experiment Experiment Termination: 2 hours per experiment
C.	Duty cycle:	Once daily; 90 days; number of simultaneous experiments to be determined.
D.	Skills:	See 5.A.
E.	Special training:	Equivalent to laboratory assistant, plus *Ad hoc* training with P.I.

6. SPACECRAFT SUPPORT

A.	Power	50 watts max
B.	Volume	2 $feet^3$
C.	Weight	50 lbs.
D.	Envelope	TBD
E.	Data	Photographs, specimens; total S/C environment including accelerations.

7. DEVELOPMENT SCHEDULE

	Phase A	Phase B	Phase C	Phase D
FY	'70	'71	'72	'73'74

8. COST $ 2. 4 M Total Cost (Includes only experiment development)

FY	'70	'71	'72	'73	'74	Flight
$(K)	200	300	500	600	600	200

EXPERIMENT DATA SHEET

THE ROLE OF GRAVITY IN INVERTEBRATE METABOLISM

---The effect of weightlessness on the general and intermediary metabolism of invertebrates

---The effects of the space environment on Invertebrate cellular metabolism

1. SPECIFIC OBJECTIVE

The goals of these experiments will be to document changes in, e.g. respiratory or intermediary, metabolic functions of invertebrates at the organism level which are related to the long term exposure to weightlessness. The experiments also will trace metabolic activity of insect cell in relation to physical structures at the subcellular level.

2. GENERAL DESCRIPTION

The first class of experimental data cited above will be derived from across-the-board observation of all test specimens in this FPE. No specific organized experiments are proposed at this time. However, when the data from the majority of the experiments described are correlated, a general picture of the metabolic response of the invertebrate organism to the weightless environment should emerge as the basis for future directed experimentation.

Cellular level experiments employing several developmental stages of Drosophila would involve exposure of numbers of test specimens to the space environment. The insects would be sacrificed and preserved at appropriate intervals, and returned to Earth for study. Enzymic activities would be assayed and subcellular structures would be isolated for electron microscopy.

3. OPERATIONAL CONSTRAINTS

Acceleration environment is critical. Engineering solutions to minimize force can be achieved. Altitude, Inclination, pointing not critical. Must be

isolated from any periodical phenomena.

4. MODE OF OPERATION

A. Man attended

B. If attached: isolated from S/C acceleration.
If detached: dockable for man access

C. Continuous operation.

5. CREW SUPPORT

A. Functions: Experiment initiation; monitor; maintain and repair. Specimen handling; specimen preservation and preparation for return; experiment termination

B. Time: Experiment Initiation: 1 hour per experiment
Experiment Operations: 1 hour per day per experiment
Experiment Termination: 2 hours per experiment

C. Duty Cycle: Once daily; 90 days; number of simultanesous experiments to be determined.

D. Skills: See 5.A.

E. Special training: Equivalent to laboratory assistant, plus Ad hoc training with P.I.

6. SPACECRAFT SUPPORT

A. Power: 25 watts max

B. Volume: 2 $feet^3$

C. Weight: 25 lbs.

D. Envelope: TBD

E. Data: Samples returned; Total S/C environment including accelerations

7. DEVELOPMENT SCHEDULE

	Phase A	Phase B	Phase C	Phase D
FY	'70	'71	'72	'73-74

8. COST Total \$1.55 M (Total Cost includes only experiment development)

FY	'70	'71	'72	'73	'74	Flight
\$ (K)	100	150	300	500	400	100

EXPERIMENT DATA SHEET

THE ROLE OF GRAVITY IN AGING IN INVERTEBRATES

---The effects of weightlessness on general age-related functions in insects.

---The effects of the space environment on cellular level phenomena and aging in insects.

1. SPECIFIC OBJECTIVE

The goals of this experimentation are to detect changes in normal aging processes in insects exposed to long term weightlessness and to identify causal relationships and mechanisms involved.

2. GENERAL DESCRIPTION

The house fly has been used for many years as the insect of choice in studies on aging. Using this work as a baseline for comparison flies of known age will be exposed to the weightless state. In one approach they might be exposed for a limited time during the pupal stage, then returned to Earth for study of the aging process. In another approach flies would be hatched on board and exposed to weightlessness throughout their entire life cycle or even several generations to observe cumulative effects.

Measurements used will include percentage of survival through each developmental stage; adult mortality counts; wing beat frequency and duration of flight; and rate of wing loss with age.

In other experiments (with Drosophila) insects which have been treated with mutagenic agents and which can be expected from experience to show somatic mutations would be exposed to the weightless environment.

If the modified somatic gene material is more susceptible to hypogravity than is the normal material, somatic abnormalities should reveal the differential susceptibility. Ultimately, by relating these somatic mutations to aging, a connection between weightlessness and aging may be established.

3. <u>OPERATIONAL CONSTRAINTS</u> - Acceleration environment is critical. Engineering solutions to minimize force can be achieved. Altitude, inclination, pointing not critical. Must be isolated from any periodical phenomena.

4. <u>MODE OF OPERATION</u>

   A. Man attended

   B. If attached: isolated from S/C acceleration.

      If detached: dockable for man access

   C. Continuous operation.

5. <u>CREW SUPPORT</u>

   A. Functions: Experiment initiation; monitor; maintain and repair; sample preservation and preparation for return; experiment termination.

   B. Time: Experiment initiation: 1 hr per experiment

      Experiment operations: 1 hr per day per experiment

      Experiment termination: 2 hrs per experiment

   C. Duty cycle: Once daily; 90 days; number of simultaneous ex-experiments to be determined.

   D. Skills: See 5A

   E. Special training: Equivalent to laboratory assistant plus <u>ad hoc</u> training with P.I.

6. SPACECRAFT SUPPORT

A.	Power	50 watts max
B.	Volume	3 ft^3
C.	Weight	50 lbs.
D.	Envelope	TBD
E.	Data	Samples returned; total S/C environment including accelerations.

7. DEVELOPMENT SCHEDULE

Phase A	Phase B	Phase C	Phase D
FY '70	'71	'72	'73-'74

8. COST - COST INCLUDES ONLY EXPERIMENT DEVELOPMENT (Total $2.1M)

FY '70	FY '71	FY '72	FY '73	FY '74	Flight
$200 K	$300 K	$400 K	$500 K	$500 K	$200 K

EXPERIMENT DATA SHEET

THE ROLE OF GRAVITY IN GENETIC PHENOMENA IN INVERTERBATES

---The effects of hypogravity on mutability in adult Drosophila.

---The effect of weightlessness on chromosomal rejoining.

---Resistance to the genetic effects of weightlessness afforded by genetic diversity.

---The effects of hypogravity in producing specific cytologically identifiable anomalies in chromosomes.

---The effects of weightlessness on radiation repair mechanisms in chromosomes.

1. SPECIFIC OBJECTIVE

The goal of these experiments is to employ the space environment, expecially weightlessness, as a tool in developing a clearer understanding of genetics in general and the role gravity plays in maintaining genetic stability in organisms.

2. GENERAL APPROACH

Numerous experiments are needed to follow up the work begun in the Biosatellite program. Further studies are needed on the mutability of reproductive cells in adult Drosophila and are planned. Biosatellite techniques will be used, but exposure to weightlessness might be up to 15-fold greater.

Another area of study will examine the effect of weightlessness on the process of chromosome rejoining. The space environment may alter the rate at which abnormal recombinations of chromosomes occur. Such studies based on Biosatellite techniques would give insight into

the intracellular phenomena involved in the normal rejoining process.

In parallel experiments would be carried out to determine whether such special genetic states, such as a high degree of heterozygosity, would tend to offset or otherwise "buffer" against such an environmental stress as weightlessness alone or in combination with other stresses.

Cytological studies of gene action are possible using physical anomalies in the chromosomes as markers. Studies of chromosomal anomalies by these techniques, after exposure of Drosophila larvae to weightlessness, could lead to identification of gene loci active in genetic responses to hypogravity. On board preservation of specimens would be followed by ground based cytological examination.

A key factor in the relationship between weightlessness and radiation damage may be the radiation damage repair system. Habrobracon would be employed, using Biosatellite techniques, to identify the role played by the repair system in cell repair in both the meiotic and the mitotic stages. Studies with this wasp would also be made to determine the threshold level of gravitational force at which "weightlessness" phenomena occur. These results would contribute directly to the "Kondo-Von Borstel" theory of gravity-action in biological systems.

3. OPERATIONAL CONSTRAINTS - Acceleration environment is critical. Engineering solutions to minimize force can be achieved. Altitude, inclination, pointing not critical. Must be isolated from any periodical phenomena.

4. MODE OF OPERATION

A. Man attended

B. If attached: isolated from S/C acceleration.
If detached: dockable for man access

C. Continuous operation

5. CREW SUPPORT

A. Functions: Experiment initiation; monitor; maintain and repair; specimen handling; cytological preparations; specimen preservation and packing for return; experiment termination.

B. Time: Experiment initiation: 1 hr. per experiment

Experiment operations: 1 hr. per day per experiment

Experiment termination: 2 hrs. per experiment

C. Duty cycle: Once per day; 90 days; number of simultaneous experiments to be determined.
ex

D. Skills: See 5A

E. Special training: Equivalent to laboratory assistant plus *ad hoc* training with P. I.

6. SPACECRAFT SUPPORT

A. Power 50 watts max.

B. Volume 3 ft^3

C. Weight 75 pounds

D. Envelope TBD

E. Data Samples and cytological preparations returned; total S/C environment including accelerations.

7. DEVELOPMENT SCHEDULE

Phase A	Phase B	Phase C	Phase D
FY '70	'71	'72	'73-'74

8. COST - COST INCLUDES ONLY EXPERIMENT DEVELOPMENT --Total $3.0 M

FY '70	FY '71	FY '72	FY '73	FY '74	Flight
$200 K	$300 K	$500 K	$900 K	$800 K	$300 K

EXPERIMENT DATA SHEET

BIORHTHMICITY IN INVERTEBRATES

---Circadian rhythms in Drosophila during orbital flight.

---Circadian rhythms in cockroaches during orbital flight.

---Biorhymicity of fiddler crab activity and respiration in orbital flight.

1. SPECIFIC OBJECTIVE

The experimental objective is to determine whether removal from the Earth's rhythmic geophysical environment will affect well-known rhythmic phenomena in activity metabolism and development in Invertebrates. Whether these periodicities remain the same, are modified, or completely disappear, the results will provide insight as to whether these rhythms are timed by autonomous, endogenous oscillator systems, or are dependent upon enogenous rhythmic inputs.

2. GENERAL DESCRIPTION

Experiments with Drosophila will depend on the known rhythm expressed as the timing between successive bursts of pupal emergence in a carefully controlled population. Changing this periodicity in earth orbit with specific physical cues and studying the phenomenon of temperature compensation are specific approaches to be employed.

The cockroach exhibits a circadian rhythm in physical activity and metabolic rate. The ability of the roach both to maintain these rhythms for long periods of time and to exhibit temperature compensation will be determined. Usual approaches to the necessary measurements will be the "activity wheel" and a microrespirometer monitoring O_2 demand.

The fiddler crab also shows similiar biorhythms in its activity and metabolism. A locomotor activity measurement device and respirometer will

provide the necessary data to evaluate this crab's ability to maintain its rhythms in an altered geophysical environment.

3. OPERATIONAL CONSTRAINTS

Acceleration environment is critical. Engineering solutions to minimize force can be achieved. Altitude, Inclination, pointing not critical. Must be isolated from any periodical phenomena.

4. MODE OF OPERATION

A. Man attended

B. If attached: isolated from S/C acceleration.
If detached: dockable for man access.

C. Continuous operation.

5. CREW SUPPORT

A.	Functions:	Experiment initiation; monitor; maintain and repair; specimen handling; specimen preservation and packing for return; experiment termination
B.	Time:	Experiment initiation: 1 hour per experiment Experiment operations: 1 hour per day, per experiment Experiment termination: 12 hours per experiment
C.	Duty Cycle:	Once per day; 90 days; number of simultaneous experiments to be determined.
D.	Skills:	See 5.A.
E.	Special training:	Equivalent to laboratory assistant, plus Ad hoc training with P.I.

6. SPACECRAFT SUPPORT

A.	Power	50 watts max
B.	Volume	2 ft^3
C.	Weight	25 lbs.
D.	Envelope	TBD
E.	Data	Specimens and recordings returned; Total S/C environment including acceleration.

7. DEVELOPMENT SCHEDULE

	Phase A	Phase B	Phase C	Phase D
FY	'70	'71	'72	'73-74

8. COST Total $3.0 M (Includes only experiment development)

FY	'70	'71	'72	'73	'74	Flight
$ (K)	200	300	500	900	800	300

EXPERIMENT DATA SHEET

THE ROLE OF GRAVITY IN INFLUENCING BEHAVIOR IN INVERTEBRATES

---Discrimination and communication in bees during long term exposure to weightlessness

---Orientation and geosensing in spiders

1. SPECIFIC OBJECTIVE

These experiments will examine the hypothesis that certain aspects of behavior in Invertebrates are cued by gravity. Anomalies found due to the absence of a physical phenomenon may, in some ways, be shown to anomalies provoked by biological or chemical stimuli.

2. GENERAL DESCRIPTION

It has been hypothesized that communicative behavior in bees is based on patterns of activity, body attitude, etc. In the absence of a gravitational force as a reference, the bee may not be able to orient. Further, perception of the locations of food sources may be compromised in the absence of gravity to provide orientational cues. Tests of the bee's ability to"percieve" food locations and to communicate this information to its co-workers in weightlessness could contribute significantly to understanding this aspect of animal behavior. Simple sugar food sources, offered with all appropriate cues except gravity, and a simple "hive" would be required. High speed motion picture photography with a synchronized audio system would record the data needed for post flight interpretation.

Gravity-sensing in spiders provides a primary cue for web-building. However webs should be built in the weightless state. Anomalies in structure can be compared with anomalies due to other experimental conditions. The

results might not only identify the g-sensory mechanism in the spider, but also assist in the interpretation of such problems drug action and mechanisms of brain damage in higher animals. Simple confinement and photographic equipment will suffice for these behavioral studies.

3. OPERATIONAL CONSTRAINTS

Acceleration environment is critical. Engineering solutions to minimize force can be achieved. Altitude, Inclination, pointing not critical. Must be isolated from any periodical phenomena.

4. MODE OF OPERATION

A. Man attended

B. If attached: isolated from S/C acceleration
If detached: dockable for man access

C. Continuous operation

5. CREW SUPPORT

A.	Functions:	Experiment initiation; monitor; maintain and repair; photography, specimen handling; specimen preservation and packing for return; experiment termination.
B.	Time:	Experiment initiation: 1 hour per experiment Experiment operations: 1 hour per day per experiment Experiment termination: 2 hours per experiment
C.	Duty cycle:	Once per day; 90 days; number of simultaneous experiments to be determined.
D.	Skills:	See 5.A.
E.	Special training:	Equivalent to laboratory assistant, plus *Ad hoc* training with P.I.

6. SPACECRAFT SUPPORT

A.	Power	50 watts max
B.	Volume	4 ft^3
C.	Weight	50 lbs.
D.	Envelope	TBD

E. Data — Specimens and films returned; Total S/C environment including accelerations.

7. DEVELOPMENT SCHEDULE

	Phase A	Phase B	Phase C	Phase D
FY	'70	'71	'72	'73-74

8. COST Total $ 1.9 M (Includes only experiment development)

FY	'70	'71	'72	'73	'74	Flight
$(K)	100	200	300	600	500	100

FUNCTIONAL PROGRAM ELEMENT VI

BIOTECHNOLOGY LABORATORY

1. DISCIPLINE

The Biotechnology Laboratory will be used for Bioscience, Biotechnology, and Space Medicine. This discription covers only the Bioscience (or Space Biology) portion.

2. PROGRAM ELEMENT - Biotechnology Laboratory

3. REQUIREMENT

Provide a space laboratory facility in which a broad spectrum of life sciences experiments can be performed making effective use of general purpose or common equipment and the skills of scientist astronauts. In particular for space biology it will continue the investigations of organisms and phenomena indicated by prior survey experiments to be most worthy of intensive further work.

4. JUSTIFICATION

a. The biological community has identified a need for a substantial amount of space flight research to gain better fundamental knowledge of the life processes through explortation of the unique space environment as a research tool.

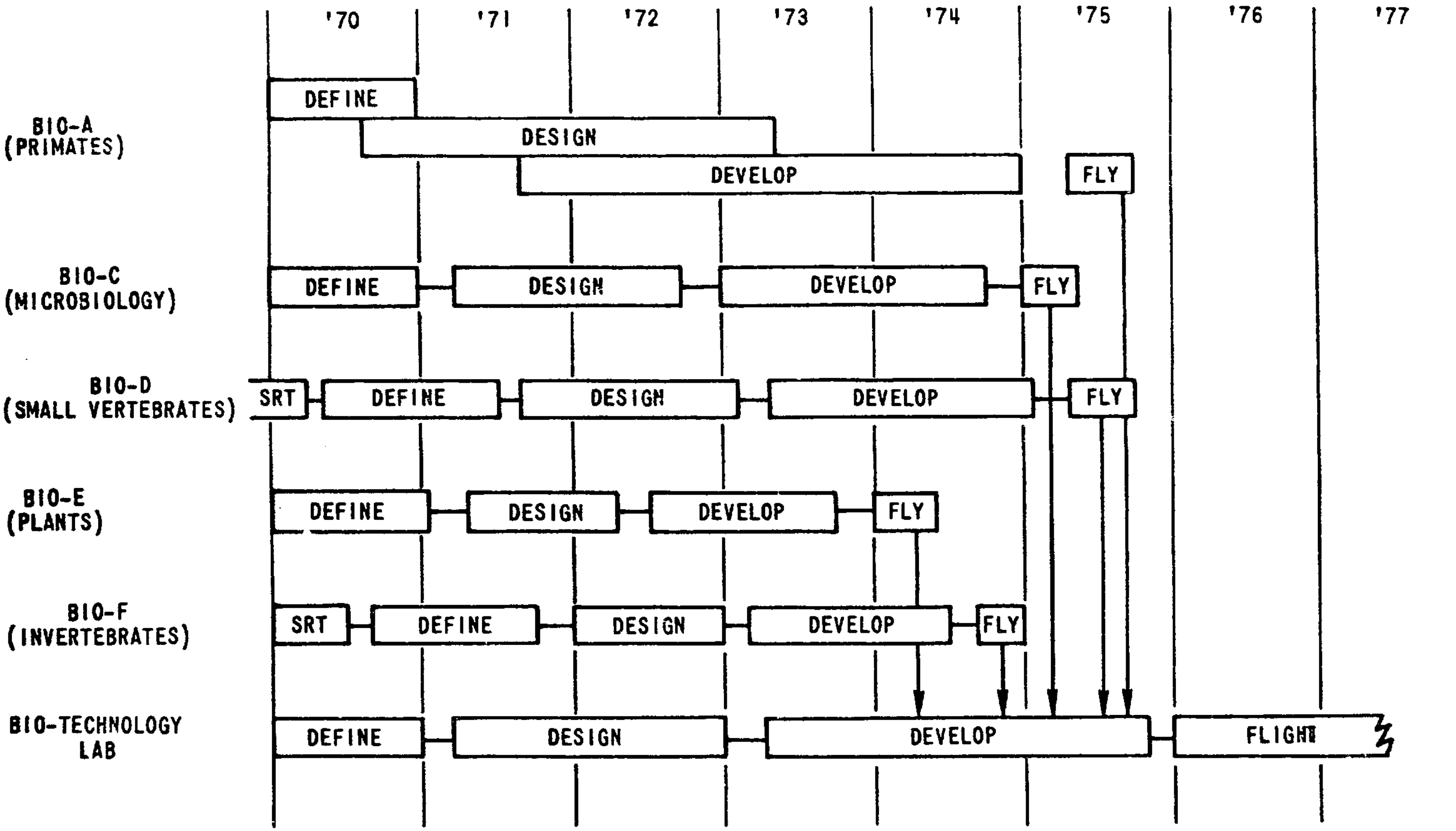
b. The presence of a life scientist astronaut can greatly enhance the scientific value of biological experiments, substantially reduce the complexity of the equipment and improve reliability.

c. The relative permanence, and the large volume and power capacity of the Biotechnology Laboratory in conjunction with the astronaut will permit the use of the equipment for repetition or variation of experiments without laborious development work. It should permit a lower cost per experiment and shorter time cycle for implementing experiments than are characteristic of the more highly automated facilities.

5. COMPONENT EXPERIMENTS

There will be many, and they are not identified now because they will be selected after the results of prior flights are known. However, it can be postulated that the elements of the experiment complex will be adaptions of the earlier elements i.e., Bio A - Primates, Bio C = Microbiology, Bio D - Small animals, Bio E - Plants and Bio F - Invertebrates.

EVOLUTIONARY PLAN FOR SPACE BIOLOGY



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CONTENTS

SUMMARY

EARTH SURVEYS

Goals and Objectives

Proposed goals, objectives and future positions of value, for the Earth Observation Program have recently been developed and documented within the context of an overall NASA planning effort. This material is synopsized in the following paragraphs.

Goals

To develop the aerospace technology and its application to the survey of the Earth and its environment for:

- The definition of the Earth's gravitational field, geometry, surface characteristics and dynamic body properties;
- The understanding of the physics of the atmosphere, the prediction of weather, and the establishment of a basis for weather modification and climate control;
- The responsible management of the Earth's resources and the human environment.

Broad Objectives

1. Provide a precise and accurate geometric description of the Earth's surface.

2. Provide a precise and accurate mathematical description of the Earth's gravitational field.

3. Determine time variations of the geometry of the ocean surface, the solid Earth, the gravity field, and other geophysical parameters.

4. Observe on a global scale the composition, structure and energetics of the atmosphere to understand atmospheric interactions: (a) within the atmosphere; (b) in response to solar inputs; and (c) at the air-Earth surface interface; and to establish a basis for experiments in the control of the weather.

5. Develop a remote sensing capability for determining the vertical structure of the atmosphere globally which, when supplemented by conventional observational techniques, will obtain the data required for large-scale, long-term weather forecasts.

6. Develop and establish a system for continuous observation of weather features so that these observations can be applied to short-term weather forecasting.

7. Continue developmental support to operational meteorological satellite systems.

8. Develop meteorological technology to support aeronautical and space systems design, testing and operations.

9. Determine the performance of remote sensors in identifying Earth resources and establish signature recognition criteria.

10. Develop sensors, subsystems and experimental spacecraft for application to future operational satellite systems.

11. Determine the scope and configuration of an operational user-oriented Earth resources survey system including ground, airborne and space components.

12. Evolve a complete data system from acquisition of remote sensor data to the eventual application by a user to a specific problem; develop techniques and formats for data handling and utilization.

Each broad objective has a number of supporting specific objectives which will not be enumerated here except for one particularly pertinent to the present study:

- Investigate the applicability of manned space systems for Earth resources survey.

Future Position of Value

The achievement of the broad objectives listed above and associated specific objectives would lead to a position of value possible in the foreseeable future which may be stated as follows:

To have in being an initial integrated system capability:

- o based on global observation and comprehensive models,
- o for the prediction, modification, or management,
- o of conditions in the atmosphere, on land, and in the oceans,
- o in the interest of man.

The elements of such a system would include:

a. The observation system

(1) space systems including rockets and polar, inclined, and geostationary satellites for Earth observation, condition monitoring, and data relay;

(2) ground systems including aircraft, ships, ground stations, buoys, balloons, and on-site sensors.

b. The data system

(1) models of the atmosphere, the dynamic Earth, the oceans, and the topography;

(2) observation data automatically updating the inputs to the model in real time.

c. The utilization system, providing accurate and timely information on which human decisions can be responsibly based

(1) in the public sector

- o weather forecast, early warning of natural disaster or pollution incursion, community status and forecast, earthquake prediction, thematic maps.

(2) in the commercial sector

- o resource exploitability analyses, industrial and urban planning, food producer and processor decisions, market forecast and action.

(3) in the institutional sector

- o continuing research on and improvement of man's environment.

(4) in the international sector

- o cooperative and coordinated weather modification and climate control actions
- o natural resource conservation agreements
- o world food planning and allocation
- o natural disaster warning and avoidance

In moving toward an integrated environmental quality management system, there are a number of major intermediate levels which will be reached. These steps are phased in time and fall into the four categories of observation, scientific understanding, prediction and management. Significant examples are:

	EARLY	MID	LATE
Observation:	Continuous thematic monitoring of the land and sea.		
Understanding:	Establish a new definitive world reference system		
		Establish comprehensive models of the atmosphere, dynamic Earth, oceans and land.	
Prediction:		Accurate 15-day weather forecasts and long range climate estimates.	
		Useful forecasts related to food production, travel, natural disasters and resources	
Management/ Modification:			Perform demonstrative experiments in hemispheric scale weather modification.
			Perform regional experiments in the management of natural resources such as water.

The system required to achieve the future position of value is by no means defined at the present time. It has been conjectured that the primary operational data collection elements of such a system would be unmanned satellites. Existing and planned meteorological, advanced technology and earth resources technology satellites might certainly constitute elements of the system or precursors to elements of the system. The role of a manned space station and bases in the development of the Earth observation system is not known at the present time. The studies of larger stations, increased size of crews with specialized competence, longer lifetimes, higher inclination orbits, and frequent shuttles from earth and return; coupled with increasing estimates of Earth observation data and antennae size requirements make it desirable to investigate the value of such stations or bases in support of the Earth Survey Program.

The intent of the Earth Observation Program in the space station-base facility is to conduct on R&D effort as one element in support of a future Earth survey operational system, which would be capable of achieving the previously stated future position of value. To conduct such an R&D effort a laboratory is envisioned which would allow study of man's contribution to Earth survey activities and which would utilize man and the other capabilities of the manned facility for the testing of hardware and development of data gathering and handling techniques.

The capabilities of a manned facility which potentially afford significant value to the Earth Survey Program are not fully understood. The following concepts are presented, however, to guide the present study.

Two major categories of effort may be considered: Data gathering and data handling. The first is the most straightforward and is best understood. It is primarily related to the testing of a wide variety of sensors over a range of variables including scan angles, seasonal changes, and the Earth's atmosphere.

Pertinent to the effective conduct of this part of the activity, is the capability for the replacement of sensors or major components thereof, and the related check-out, calibration, servicing, and maintenance. While repair is a consideration, the demonstrated high reliability of space hardware makes this appear to be somewhat less important than the ability to replace old sensors after a period of testing with new or modified equipments. The Earth-to-space shuttle is an inherent ingredient of a continuing test program of new sensors. Subsequent paragraphs of this Work Statement will present certain descriptive material pertinent the sensors. It is important to note that these sensors are typical of those now under study and are primarily useful in developing laboratory design which

could be useful for testing a wide variety of sensors. The descriptions should not be construed as specific instruments committed to the space station-base.

In considering sensor replacement, particular attention should be paid to antenna considerations. The microwave equipments for Earth resources are tending towards longer wavelength with inherently larger antennas. The laboratory must be able to accommodate these large and varying antennas.

The second major category of consideration is onboard data handling. While less straightforward, it is also potentially more important. Several concepts need to be considered. The simultaneous operation of many Earth observing sensors with direct or delayed RF transmission of data to Earth should be evaluated. It is expected that this will result in an exceptionally large requirement which may or may not be feasible to handle.

The second consideration involves onboard screening, processing, synthesizing, and analysis of data onboard the spacecraft with only selected or processed portions of the data being relayed to Earth. The intent of this approach is to relieve the total data problem nearer the source. The ability to effect such a goal is dependent on appropriate laboratory data handling facilities and specialized crew abilities. The shuttle with the ability to frequently return raw film and tape to Earth is also a pertinent consideration in this data handling approach.

A minimum of guidance as regards type and sizes of data handling equipments is available at this time and consequently must be developed within the context of this study to the extent of scoping the laboratory.

In summary, there are two key features in considering an Earth Survey laboratory on a manned space station-base. It must be capable of updating and replacing the test hardware and secondly, it must make provision for the supporting equipments which allow the study of manned-onboard handling of the incoming data.

5.11.2 Physical Description. The major components of the Earth observations laboratory would include the sensor test area, sensor work area, command and data acquisition area, and data handling area, remote maneuvering satellites, and unmanned return vehicles.

5.11.2.1 Sensor Test Area. This area is where the sensors are physically located during their operation. Characteristically, it must

provide a broad Earth-looking field of view with numerous and/or large parts equipped with high quality materials designed to minimize the distortion introduced into the data from environmental effects. Similarly, it must provide location and possible access to Earth-looking antenna systems. Space and design of such an area must consider the ability of changing out and replacing the initial sensors. Sizes and other pertinent material for the design of the area should be derived from the sensor description material.

5.11.2.1.1 Sensor Categories. The types of sensors under consideration are divided into four major categories. This includes photographic (visible or near-IR), infrared, microwave and "special". The photographic sensor system will be used for location referencing, general mapping, multispectral investigation and general support of the other sensors. A relatively large camera, a 'gang' of smaller cameras, and a stellar camera capability are envisioned. Onboard processing of film up to 9" format and both black and white and color is required.

The infrared sensor system should include accommodation for one multichannel scanner of up to 12 channels and three spectrometers. These systems would operate in the .3 to .15 micron range. The scanners and one spectrometer would generally be Earth studies while the other two spectrometers might be for supporting atmospheric measurements or for the development of new atmospheric measurement devices.

The microwave system includes both active and passive types. A multifrequency side-looking imaging radar and an active-passive imaging system capability would be required. Both systems would operate in the 1-10 GHz range. The capability for testing two passive microwave radiometers in the 1-20 GHz and 1-90 GHz frequency region would be required.

Capability should be provided for testing a variety of sensors developed for special purposes. A typical group of these sensors might include an absorption spectrometer, Fraunhofer Line Discriminator, Visible Spectrum Polarimetry, UHF sferics, and a laser Altimeter.

5.11.2.2 Laboratory Work Area. This area would be used for the receipt, checkout, servicing, calibration, repair, and change of equipment components. It should contain the equipments to support these functions. It is estimated that the area of the lab would be 200 square feet or larger.

5.11.2.3 Command and Data Acquisition Area. Would allow the control of the data taking portions of the experiments. It should include the

necessary communication to ground and space station command area. It should allow for the monitoring of all data being taken. Supporting equipments such as TV mon toring of ground track should be incorporated. It should include the capability for storing the data either in a laboratory or central space station data receiving facility and/or transmission of data to ground.

5.11.2.4 Data Handling Area. The data handling area should have the capability to call up and display all stored data. Minimal equipments would include the capability for review and screening of data for basic "electronic" quality. Second order capability would allow screening of data for experimental usefulness. This would require systems such as described in reference . An additional degree of capability would involve the inclusion of computer capability of the equivalent of that contained in an IBM 360-44.

5.11.2.5 Remote Maneuvering Satellite. These devices (3-6) will be a facility that will allow instrumentation to be flown independently of the space station. The satellites will be launched with the space station module and once orbit is achieved, will be capable of being ejected and changing orbit operated by remote control from the space station. Hence, the satellites will have stability, propulsion, power and communication capabilities.

5.11.2.6 Unmanned Return Vehicle. In anticipating a requirement for an early return of film, malfunctioning parts, etc., vehicles such as those used in the Discoverer Program would be ideal and have the capability of serving some of the other disciplines. A number of these vehicles should be included to provide some timely early return capability base on the normal logistics capability. It would augment the use of the shuttle service for special requirements which were not time compatable with the shuttle.

5.11.3 Weight and Envelope Data. In order to assist in developing criteria for the design of a laboratory, descriptive information of a number of Earth observation sensors is presented. It should be emphasized that the intended use of this information is to derive a set of generic requirements for the facility rather than to effect detail integration studies of these particular sensors. Sensors to be actually flown are under study and cannot be specifically defined at this time. The emphasis, therefore, should be on designing a facility which has the capability of handling sensors of this type, e.g. earth looking, large data rates, large antennas, rather than a specific set of instruments.

5.11.3.1 Photographic System. Initially consists of a 9" camera, a set of 70mm cameras, and a stellar reference camera.

5.11.3.1.1 9" Camera:

Weight: 200 pounds
Volume/Dimensions: 30"x30"x24"
Power: 250 watts (avg)-28VDC
400 watts (pk)
10 watts (stand by)
Data: 4 channel analog (Hk) film
Field of view: 100°
Thermal Control: 100°F Max in operation.

5.11.3.1.2 70mm Cameras:

Weight: 55 pounds
Volume: 6 cameras at 6"x5.5"x3.75"
Power: 5 watts (Pk, avg, S.B.) 28 VDC
0 watts
Data: Film (18 pks at 4"x4"x4"-24 lbs total)
Field of View: 40°
Thermal Control: 100°F Max in operation.

5.11.3.1.3 Stellar Reference Camera:

Weight: 80 pounds
Volume/Dimensions: 14"x12"x12"
Power: 50 watts (pk)
0 watts (standby)
Data: Time
Field of view: 20°
Thermal Control: 100° Max.

5.11.3.2 Infrared Systems

5.11.3.2.1 Multispectral Infrared Scanning System. This instrument will consist of a space design of a presently in-development aircraft instrument.

Weight: Scanner-60 pounds;
Electronics-10 pounds.
Volume: 8"x12"x30" and 6"x12"x12"
Power: 120 watts-peak (28VDC)
160 watts-average
20 watts-standby
Data: 5 analog channels DC to 120KC
Field of view: ±40°
Thermal Control: Required cryogenic cooling.

5.11.3.2.2 Wide Range Spectrometer:

Weight: 58 pounds
Volume/Dimensions: 23"x8"x15"
Power: 14 watts (average)
25 watts (peak)
0 watts (standby)
Data: Analog 8-bilevel channels
8-analog channels
1-digital channel @ 3.75 KBPS
Field of View: 5°
Thermal Control: Cryogenic cooling.

5.11.3.2.3 Infrared Atmospheric Sounder

Weight: 25 pounds
Volume/Dimensions: 10"x10"x13"
Power: 50 watts (average)
60 watts (peak)
40 watts (standby)
Field of View: 3°
Thermal Control:

5.11.3.2.4 Short Wavelength Spectrometer:

Weight: 50 pounds
Volume/Dimensions: 9"x16"x24"
Power: 50 watts average
Data: 20 KBPS
Field of View: 1°
Thermal Control: 150°F

5.11.3.3 Microwave (Active and Passive) System:

5.11.3.3.1 Passive Microwave Imager:

Weight: Electronics 50 pounds
Antenna 50 pounds
Volume/Dimensions: Electronics: 24x24x24"
Angenna: 72"x72"x6"
Power: 175 watts peak
150 watts average
Data: 70mm film; 10 samples/sec. analog
Field of View: 120°
Thermal Control: 150°F

5.11.3.3.2 Multifrequency Microwave Passive Radiometry:

Weight: 100 pounds
Volume/Dimensions: 4 cubic feet
Power: 100 watts average
Data: 3.75 KBPS
Field of View:
Thermal Control:

5.11.3.3.3 Microwave Temperature Sounder:

Weight: 100pounds
Volume/Dimensions: 4 cubic feet
Power: 100 watts average
Data: 150 BPS
Field of View:
Thermal Control:

5.11.3.3.4 Radar Imager:

Weight: 100 pounds
Volume/Dimensions: 11"x24"x12"
Power: 400-700 watts peak
Data: 50 MBPS
Field of View: 10°
Thermal Control: $150^{\circ}F$

5.11.3.3.5 Active-Passive Microwave Imager:

Weight: 80 pounds
Volume/Dimensions: 2 cubic feet
Power: 50 watts
Data:
Field of View:
Thermal Control:

5.11.3.4 Other Sensor Systems:

5.11.3.4.1 Visible Spectrum Polarization:

Weight: 50 pounds
Volume/Dimensions: 10"x18"x10"
Power: 100 watts peak
50 watts average
10 watts standby
Data: 32 SPS analog
Field of View: 120°
Thermal Control: $150^{\circ}F$

5.11.3.4.2 UHF Sferics:

Weight: 22 pounds
Volume/Dimensions: Antenna-18"x18"x5"
Electronics: 9"x18"x6"
Power:
Data: 300 BPS
Field of View: 120°
Thermal Control: 150°F

5.11.3.4.3 Absorption Spectrometer:

Weight: 100 pounds
Volume/Dimensions: 24"x8"x34"
Power: 22 watts average
Data: 400 BPS
Field of View: 20°
Thermal Control: 150°F

5.11.3.4.4 Laser Altimeter:

Weight: 80 pounds
Volume/Dimensions: 20"x20"x20"
Power: 20 watts
Data: 8 BPS
Field of View: 1°
Thermal Control: 150°F

5.11.3.4.5 Fraunhofer Line Discriminator:

Weight: 150 pounds
Volume/Dimensions: 36"x8"x20"
Power: 45 watts average
60 watts peak
Data: 40 KBPS
Field of View: 15°
Thermal Control: 100°F

5.11.4 Experiment Program. The Space Station-Space Base will be a research and development facility which will be utilized due to its advantageous Earth orbital location, to conduct studies in the various Earth surveys discip'ines, develop instrumentation and analysis and data handling techniques. It will be used to a much larger extent thatn the aircraft are used now.

5.11.5 Performance Requirements and Subsystems. As this is a research and development type facility, it will be expected to support the conduction of the many thpes of functions found in a laboratory. The types of requirements described in 5.11.2 and 5.11.3 are typical of those anticipated in any earth based laboratory. However, certain unique requirements can be established for an earth-orbiting facility. The sensors must be Earth oriented, with an attitude hold capability of $.05^{\circ}$/sec in all axis and the accuracy to which any particular sensor is directed must be known to 1°. Precise timing of the operation of the sensors, hence data acquisition, must be known.

5.11.6 Recommended Mode of Operation. Due to the varied types of data that will be obtained by the sensors and the types of studies that will be conducted, it is unknown as to what systems will be operating sequentially or simultaneously. However, the space station should have the capability of supporting the operation of all the sensors simultaneously. It is recognized that the operation of the laboratory equipment must be held within the capability of the laboratory facility in Earth orbit as on land. The space station or base overall design will determine this capability which will vary hourly.

5.11.7 Definition of Station Interface. This will be determined by the spacecraft designer, the requirements submitted in 5.11.2 and 5.11.3, and subsequent studies.

5.11.8 Role of Man. Man's exact role in a space laboratory will vary according to laboratory capability. For Earth resources and meteorology studies, the following types of tasks can be assumed feasible.

5.11.8.1 Operation. Target selection, adjust sensors, orientation, alignment, boresighting, taking data (technician type).

5.11.8.2 Observation. Monitor data, target description, preliminary data screening (scientist type).

5.11.8.3 Maintenance. Trouble shoot, module, part and instrument replacement, calibration and checkout (technician type).

5.11.8.4 Analysis. Process and evaluate data, target planning, ground data verification, determine sensor operation, technique research and development (meteorologist, scientists types).

5.11.8.5 Operational Reporting. World weather watch and prediction, seasonal crop, fish and timber monitoring, map making, geological and oceanographic studies (scientist types).

5.11.9. Cost and Schedule. Unknown to cost and will conform to space station schedule.

5.11.10 Available Background Data. Past Earth resources and meteorology studies.

5.11.11 Safety Analysis. None.

FUNCTIONAL PROGRAM ELEMENT I

1. DISCIPLINE:

   SPACE APPLICATIONS - Earth Resources and Meteorology

2. PROGRAM ELEMENT: Space Applications Experiments Package - First Workshop (1970-1972)

3. REQUIREMENT:

   a. To develop methods to monitor activities of man and to identify earth resources from space, using essentially off-the-shelf hardware.

   b. To assist in the development of techniques of a better global weather observation system.

REVISION PENDING

4. JUSTIFICATION:

   a. To perform a comprehensive study of the Earth's surface from space is a complex problem. Since no one remote-sensing system can completely satisfy all of the scientific requirements it is only by adopting a coordinated approach that the objectives can be achieved. The Earth Resources Survey experiments contained in this approximately 500-pound Space Applications package have been selected for their ability to contribute toward the advancement of this goal.

   b. Present monitoring of world-wide atmospheric conditions is insufficient to support long-range weather forecasting. Also, additional understanding of the science of the atmosphere is necessary. These purposes can be served by space-borne experiments that will support the Global Atmospheric Research program and the objectives of the World Weather Watch.

   This package of experiments consists of intruments which have progressed to such a point that they can fly in the 1970-1972 time-frame. The package can be accommodated by the First Workshop and is a logical forerunner to the more complex packages of 1973-1975.

5. COMPONENT EXPERIMENTS:

   S100, Metric Camera
   S101, Multiband Photography
   S102, Dual-channel Scanner/Imager
   S103, Short Wavelength Infrared Spectrometer

S075, Microwave Radiometer, electrically scanning
S049, Infrared Interferometer
S043, Infrared Spectrometer
Metric and multiband cameras provide cartographic/ topographic background for spectral and radiance information given by imagers and other sensors.

6. DESCRIPTION:

A 500-pound package of 4 Earth Resources Survey and 3 Meteorology experiments selected for flight on an early AAP mission (AAP-2) and which will provide preliminary data and flight experience on which to base the definition and development of the experiment packages of the Intermediate Workshop and the post-1975 time-frame.

S100-S103, inclusive, are primarily Earth Resources Survey experiments and will provide data for users in the disciplines of Hydrology, Geology, Geography, Agriculture, Forestry, and Oceanography, as well as for Geodesy and Cartography. S043, S049 and S075 are primarily meteorological. Detailed instrument descriptions are attached.

7. SPECIAL CONSIDERATIONS:

a. Due to its physical size, the metric camera requires additional structural weight of 200 pounds in order to mount it on the spacecraft.

b. The AAP spacecraft has an 8-bit word capability and several experiments require 10-bit word accuracy.

c. Several experiments require attitude and rate history to one degree. Spacecraft timing is recorded to one-tenth second; some experiments require timing to 0.01 second.

d. The probable orbital inclination for the first workshop will be considerably less than that required for experiments which monitor strong air-mass contrasts and a diversity of surface test sites. A near-polar orbit is preferred for meteorology and a minimum orbital inclination of 50° is strongly desired by Earth resources sensors.

EXPERIMENT DATA SHEET

METRIC CAMERA - EARTH RESOURCES (S100)

1. SPECIFIC OBJECTIVE: To explore the potential of stellar oriented metric photography for cartographic and geodetic purposes. Accurate base maps are needed to apply the results of all other orbital sensors.

2. GENERAL DESCRIPTION: A ground-looking metric camera is coupled with a stellar camera for observation. An automatic picture taking sequence will be initiated over selected areas of the Earth. EVA film change is required.

3. OPERATIONAL CONSTRAINTS:

Orbital altitude	- 100-125 nm preferred 270 nm acceptable
Inclination	- 90° preferred - 50° and 28.5° acceptable
Time of year	- 2nd quarter preferred, rest acceptable
Lighting	- sun elevation greater than 30°
Clouds	- less than 30% cover
Viewing	- Earth nadir, unobstructed field 100°, 25° stellar stellar camera 15° above horizon
Stabilization	- attitude local vertical attitude rate 0.05 deg/sec pointing accuracy ± 1.5°

4. MODE OF OPERATION:
Manned, attached, intermittent

5. CREW SUPPORT:
Representative Timeline Sequence:
(1) Set up & visual ground contact, check cloud cover
(2) SW to Standby
(3) Visually Acquire Target Start Point
(4) Assess Target Conditions
(5) SW mode to Auto; SW to on
(6) Describe & Record Target Conditions; Monitor Experiment
(7) SW off

∿5 min 1 min 1/2 min ∿10 min

One crewman, requiring 5 min setup, 12 min operation per cycle. Desired number of cycles 80 (intermittent operation).

6. SPACECRAFT SUPPORT:

Power - 250 watts - 28 VDC average
400 watts peak
10 watts standby

Volume - Ascent 21,600 cu. in. (30"x30"x24")
Return 4,000 cu. in. (14"x12"x12") (2)
(10"x6"x6") (2)

Weight - Camera 200 lbs.
film 80 lbs.

Data - Analog 4 channels (housekeeping)
Film 23x23 cu. format

7. DEVELOPMENT SCHEDULE:

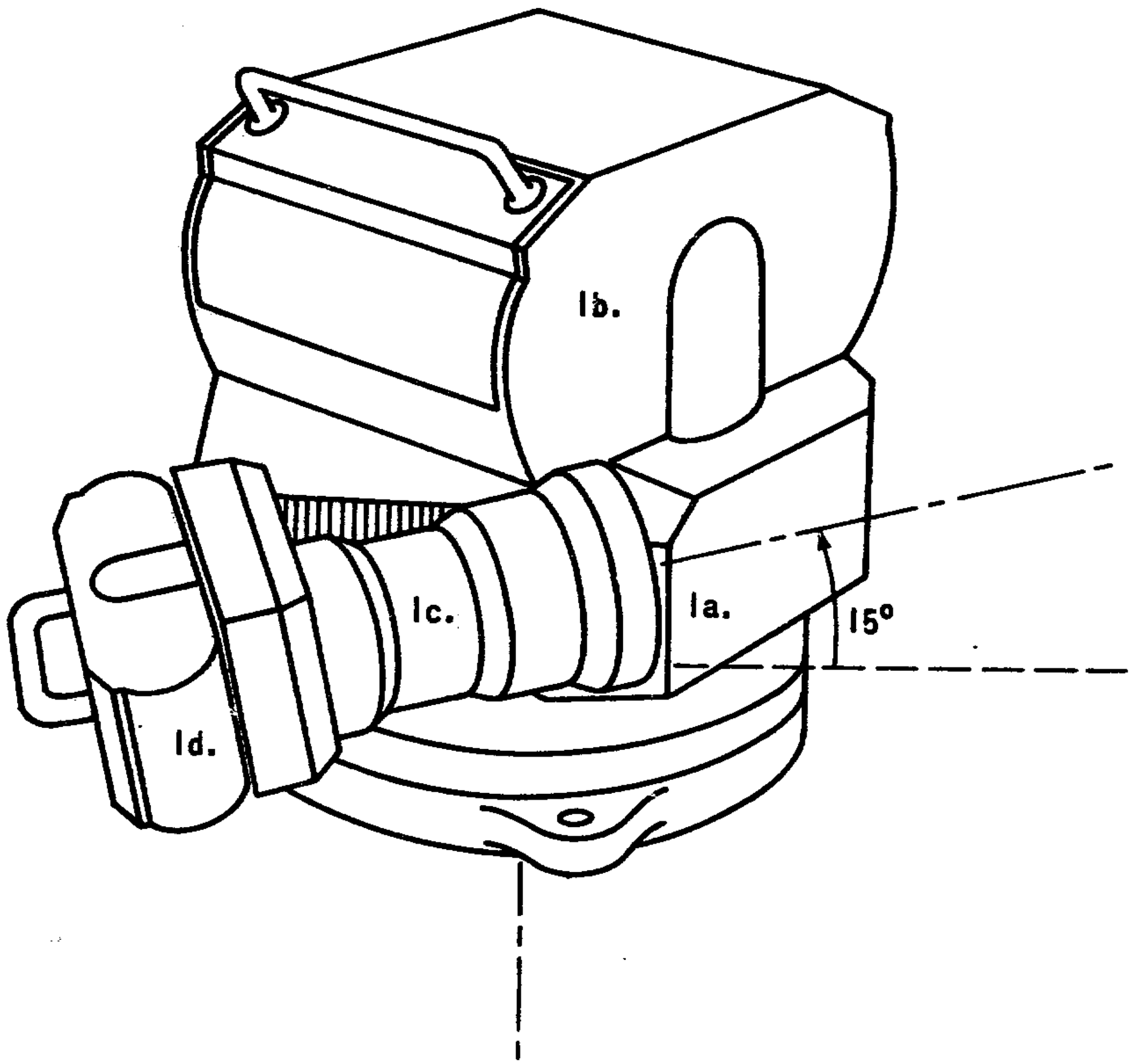
Approved by MSFEB November 1967

8. COST:

Cost Data: Experiment Equipment
FY 68 275 DEF FY 69 927K FY 70 73K
FY 71 200K FY 72 100K FY 73 0

Total Cost: 1.1 M

EXP. NO. S100
TITLE: METRIC CAMERA



ASSEMBLY #1

1a. FRAME CAMERA
1b. FILM MAGAZINE FOR FRAME CAMERA
1c. STAR CAMERA
1d. FILM MAGAZINE FOR STAR CAMERA

SCHEMATIC OF S100 METRIC CAMERA (WITH STELLAR)

EXPERIMENT DATA SHEET

MULTIBAND PHOTOGRAPHY - EARTH RESOURCES (S101)

1. SPECIFIC OBJECTIVE: To determine the extent to which multispectral photography from space may be effectively applied to the Earth Sciences.

2. GENERAL DESCRIPTION: Six Hasselblad 500 electric cameras with 120 mm focal length lenses are mounted in a common frame, with shutters synchronized to provide simultaneous exposure. Films and filters will be selected to cover the spectral region 0.4 to 0.92 microns.

3. OPERATIONAL CONSTRAINTS:
Altitude 100-125 nm preferred
Inclination 50° preferred
Time of year 2nd and 3rd quarter preferred
Sun elevation greater than 30°
Cloud cover less than 30%
Viewing direction at Earth nadir point
Orientation should provide film travel parallel to ground track
Attitude rate 0.05 deg, pointing accuracy ± 2°
Unobstructed field of view 40°
Special Requirements: Optical quality window; film return; no light in FOV

4. MODE OF OPERATION:
Manned, attached, intermittent
Man selects and identifies targets, gives voice annotation

5. CREW SUPPORT:
One crewman, 5 min setup, 12 min operation, minimum of 15 operation cycles required

Representative Cycle Timeline:
(1) Setup; visual contact; check cloud cover
(2) SW on
(3) Visual Acquisition of Target start point
(4) Assess Target Conditions
(5) SW to Auto. mode
(6) Describe and record target conditions; monitor exp. equipment
(7) SW mode off; SW off

∿5 min   1 min   1/2 min   ∿10 min

Film change required
Target selection support from ground crew required

6. SPACECRAFT SUPPORT:

Power - internal batteries on cameras
5 watts on controls
Volume - Ascent 1908 cu. inches
Return 1152 cu. inches
Weight - Ascent 55 lbs.
Return 24 lbs.
Envelope - 6 times 6"x5.5"x3.75" } ascent
18 times 4"x4"x4"
once 2"x2"x3"
18 times 4"x4"x4" return
Data - 70 mm film, 3 magazines per camera

7. DEVELOPMENT SCHEDULE:

Approved by MSFEB November 1967

8. COST:

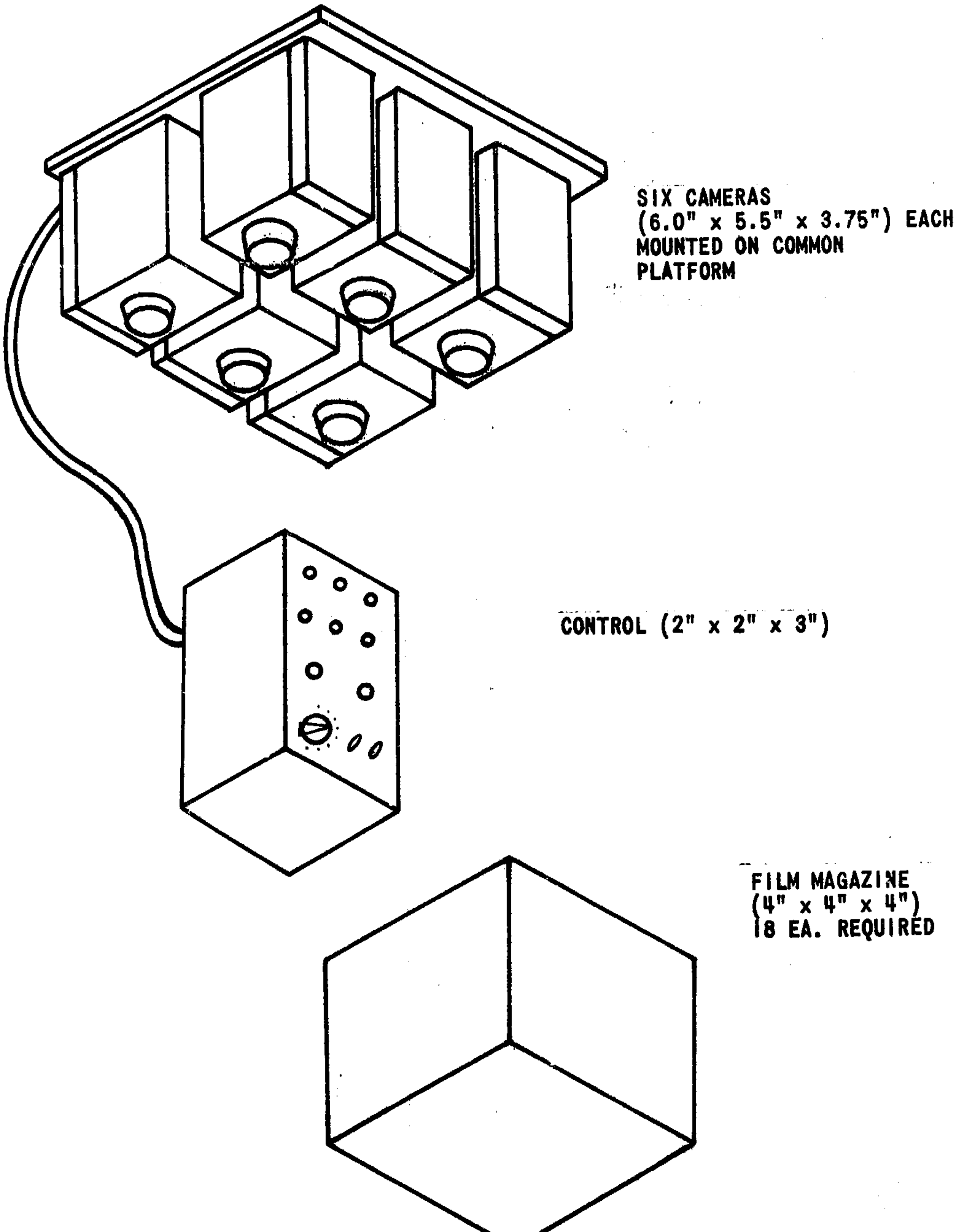
Cost Data: Experiment Equipment

FY 68 100 DEF	FY 69 275K	FY 70 325K
FY 71 228K	FY 72 100K	FY 73 0

Total Cost: 600K

EXP. NO.: S101

TITLE: MULTIBAND PHOTOGRAPHY



EXPERIMENT DATA SHEET

DUAL CHANNEL SCANNER IMAGER, EARTH RESOURCES (S102)

1. SPECIFIC OBJECTIVE: To demonstrate the role of the multiband scanner imager in identifying terrain features, crops, soils, and water pollution.

2. GENERAL DESCRIPTION: Instrument will record in graphic form the terrain radiance as observed simultaneously in the 0.6 - 0.7 and 10.0 - 12.5 μ spectral bands. A scanner mirror with a field of view of one milliradian and total scan angle of 80, scans the terrain beneath the vehicle and across the ground track. Radiation is reflected through a telescope onto a beam splitter and is focused onto a cryogenically coated thermal detector.

3. OPERATIONAL CONSTRAINTS:

Orbital altitude	- 100-125 nm preferred 270 nm acceptable
Inclination	- 50° preferred
Stabilization	- altitude local vertical altitude rate 0.4 d/s (know to 0.05 d/s) exp. pointing accuracy ± 2 deg (know to 1 deg)
Pointing	- Earth, local vertical
Lighting	- sun elevation greater than 30 deg
Time of year	- 2nd and 3rd quarter preferred

4. MODE OF OPERATION:
Manned
Attached and boresighted with S103
Film return required

5. CREW SUPPORT:
One crewman
Representative Crew Timeline - one cycle:
(1) Turn SW to standby
(2) Acquire Target Start Point
(3) Assess Target conditions
(4) Set mode control; sw, on
(5) Voice Recording of target conditions monitor exp. equip.
(6) sw, off

5 min 1 min 10 min
Skills site identification

6. SPACECRAFT SUPPORT:

Weight	-	ascent 100 lbs.
		return 5 lbs.
Volume/dimensions	-	ascent 4050 cu. in. (6"x9"x18")
		(12"x9"x18")
		(9"x9"x18")
		return 243 cu. in. (9"x5"x3"x2 ea)
Power	-	average 50W (28V) 10W (115V) (400cps)
		peak 75W (28V) 10W (115V) (400cps)
Data	-	Anolog, 10ch 0.15ps (housekeeping)
		Digital, Video: 2ch (2.5-100KHz)
		(near time for part of mission)
		Film 70 mm (2 rolls)

7. DEVELOPMENT SCHEDULE:

Approved by MSFEB	November 1967
	Phase D
Start	January 1969
End	1 year after mission

8. COST:

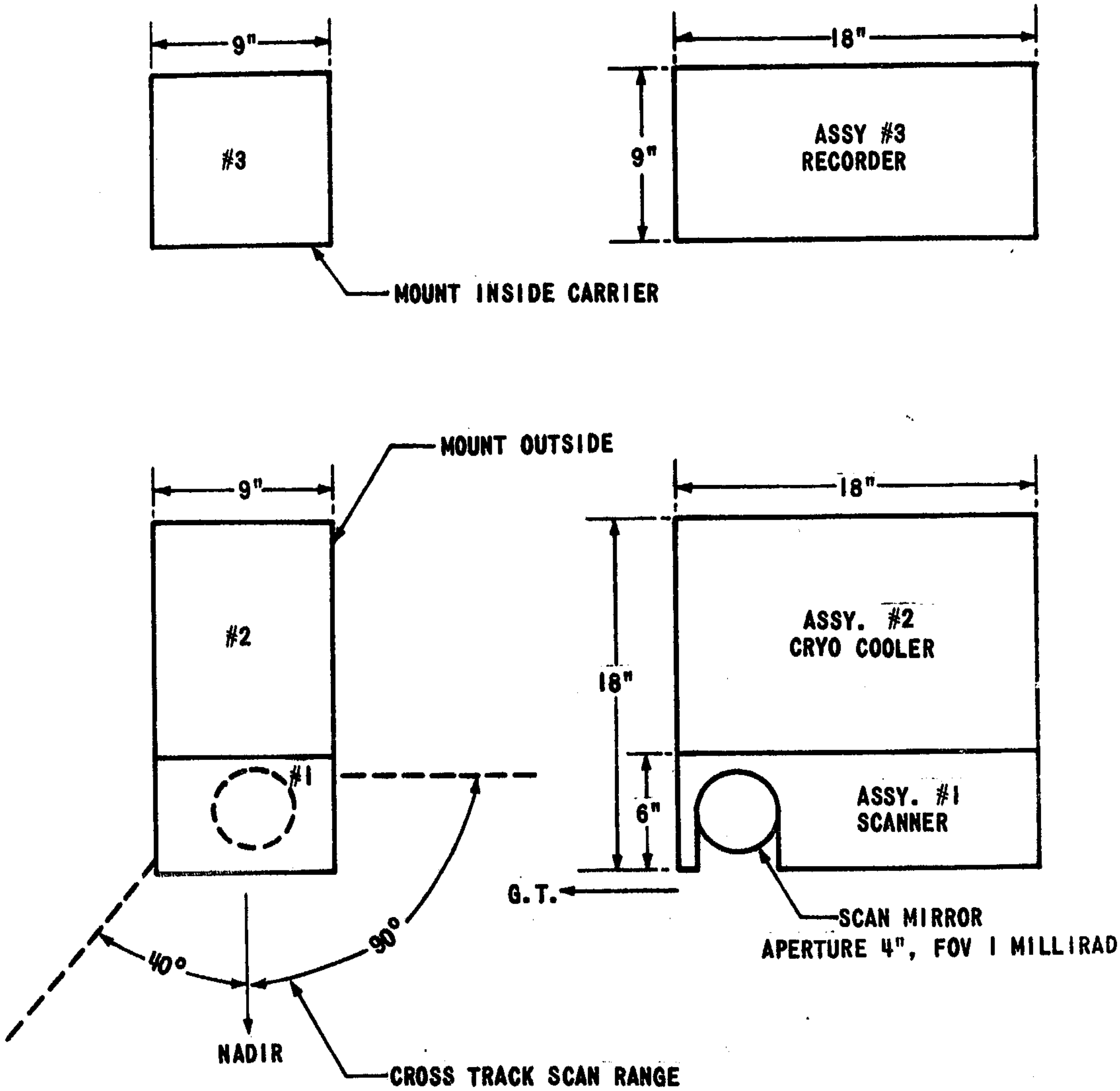
Cost Data: Experiment Equipment

FY 68 303 DEF	FY 69 855K	FY 70 1309K
FY 71 351K	FY 72 250K	FY 73 0

Total Cost: 2.5M

EXP. NO. S102

TITLE: DUAL CHANNEL SCANNER



S102 DUAL CHANNEL SCANNER (SCHEMATIC SKETCH)

EXPERIMENT DATA SHEET

SHORT WAVELENGTH IR SPECTROMETER - EARTH RESOURCES (S103)

1. SPECIFIC OBJECTIVE: To determine how accurately the spectral reflectance from terrain features can be recorded in space and to what extent it is modified by atmospheric effects.

2. GENERAL DESCRIPTION: The instrument consists of a pair of accurately boresighted telescopes, each having a 6 inch aperture and a field of view of one milliradian square. The spectral range is from 0.4 to 2.5 microns.

3. OPERATIONAL CONSTRAINTS:
Altitude - 100-125 nm preferred
270 nm acceptable
Inclination - 50° preferred
Time of year - 2nd and 3rd quarter preferred
Sun elevation greater than 30°
Do not operate over cloud cover
Attitude rate 0.4 d/s
Pointing accuracy ± 2°
Unobstructed FOV - 1 mrad (6"x13")

4. MODE OF OPERATION:
Manned, attached, intermittent

5. CREW SUPPORT:
One crewman, 5 min setup, 11 min operation,
Min. required six operation cycles per day
Skills required in site identification
Real time voice annotation
Other - Requires time correlation with S102.
Aircraft and ground surface operations coordinated with spacecraft operations where possible.
Representative crew timeline per cycle:
(1) Sw. on Warmup
(2) Sw Calibrate
(3) Sw Operate
(4) Target Surveillance
(5) Sw Calibrate
(6) Sw Off
5 min 10 min 15 sec
15 sec

5 min warmup and 15 sec calibration pulse mode required. Data taking mode shall be at least 10 min.

6. SPACECRAFT SUPPORT:
Power - Average 38W (28VDC), 10W (115V, 400cps)
Peak 65W (28VDC), 10W (115V, 400cps)
Volume - ascent 3456 cu. in.
return none
Weight - ascent 50 lbs.
return none
Envelope - 9"x16"x24"
Data - digital 9.6 Kbps per channel (science, 2 channels, 8 bit words)
0.8 bps per channel (housekeeping, 5 channels, 8 bit words)
Special Requirement: Accurately boresighted with S102. Desire two maneuvers to look at one target through different angles.

7. DEVELOPMENT SCHEDULE:
Approved by MSFEB November 1967

8. COST:
Cost Data: Experiment Equipment

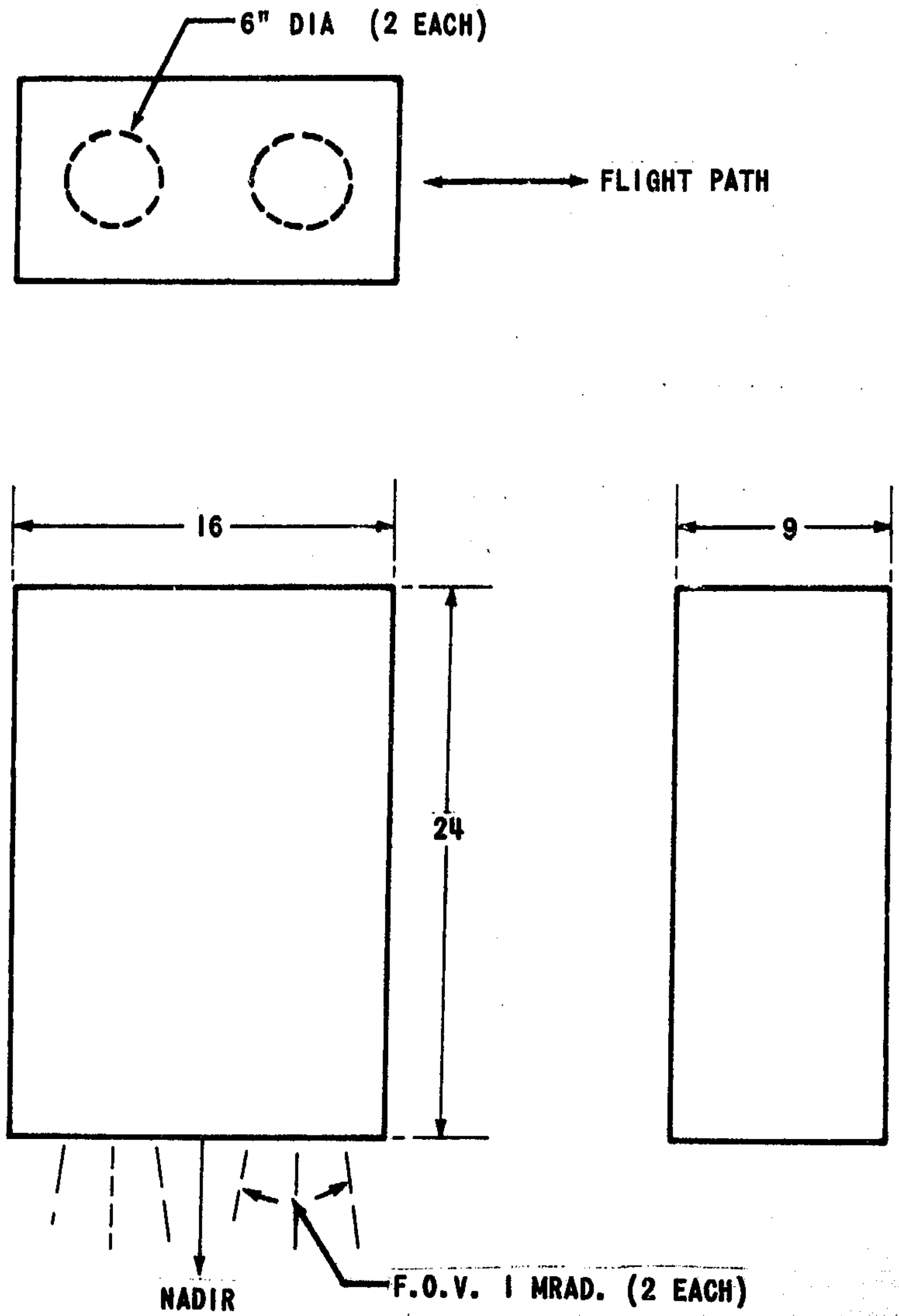
FY 68 190 DEF	FY 69 540K	FY 70 894K
FY 71 201K	FY 72 150K	FY 73 0

Total Cost: 1.7M

EXP. NO. S103

TITLE: SHORT WAVELENGTH SPECTROMETER

VII EXPERIMENT SCHEMATIC (DIMENSIONS IN INCHES)



EXPERIMENT DATA SHEET

IR INTERFEROMETER SPECTROMETER, METEOROLOGY - EARTH RESOURCES (S049)

1. SPECIFIC OBJECTIVE: To construct detailed vertical temperature and water vapor profiles, to measure O_3 concentration, and to detect and measure minor atmospheric constituents.

2. GENERAL DESCRIPTION: A Mickelson-type interferometer spectrometer incorporating a solid neon cooled Ge:Cu (copper doped germanium) detector will be used to make interferograms of the spectrum of the incident radiation from 454 to 2000 wave numbers (5μ to 22 μ) within its 2° field of view. Making the inverse Fourier transformation by a digital computer program the spectrum will be reconstructed to 5 wave number resolution.

3. OPERATIONAL CONSTRAINTS:

Inclination	- 50° or 90° acceptable
Altitude	- 100-125 nm
Time of year	- 3rd quarter
Lighting	- various lighting conditions including dark
Stabilization	- attitude ± 5° from local vertical attitude rate 0.05°/sec. max. exp. pointing accuracy ± 1°

4. MODE OF OPERATION:
Automated
Attached
Intermittant

5. CREW SUPPORT:
Number of Operations Cycles: Min Req. 50 good targets
Desired continuous operation

Crew
Crew activity description: No. crewmen 1
Crew time per cycle: Setup 1 sec - Operation 30 sec to 2 min - Standby surveillance as possible
Skills: Recognize, acquire with instrument, and describe meteorological phenomena of interest
EVA's: None

6. SPACECRAFT SUPPORT:
Weight - ascent 58 lbs.
return 0

Volume/Dimensions - ascent 3072 cu. in. 23"x8"x15" 8"x6"x6.5"
return 0

Power - Average 14W
Peak 25W
Standby 0
Total (KWH) 7 Kwh

Data - Analog 8 bi-level channels at 1sps } 8-bit accuracy
8 analog channels at 1sps
Digital 1 channel @3.75Kbps in 12-bit words
Film from "operational" camera only

7. DEVELOPMENT SCHEDULE: Deliver Flight Hdw. 10-1-70

	Phase A	Phase B	Phase C	Phase D
Start				10-1-68
End				11-1-70

8. COST:

Cost Data: Experiment Equipment
FY 68 470 DEF FY 69 480K FY 70 960K
FY 71 157K FY 72 100K FY 73 0

Total Cost: 1.5M

EXPERIMENT DATA SHEET

MICROWAVE RADIOMETER, ELECTRONICALLY SCANNING - EARTH RESOURCES (S075)

1. SPECIFIC OBJECTIVE: To map brightness temperature of atmosphere (clouds and cloud water) and ground and sea temperature contribution. Potential applications in sea ice, sea state, hydrology and geology.

2. GENERAL DESCRIPTION: The equipment consists of a 19.3 ghz receiver, electronically scanned antenna (± 50°), data, processor and power convertors. It will receive the reflected solar and emitted thermal radiation from Earth, compare with internal calibration standards, and digitize the data.

3. OPERATIONAL CONSTRAINTS:
   Altitude - no preference, but must be known for antenna design
   Inclination - 50° preferred
   Time of year - 2nd quarter prefered
   Attitude - ± 2°, rate 0.5°/sec
   Unobstructed FOV - 4°x120°
   Special requirements - 2400 cycle sync. required

4. MODE OF OPERATION:
   Automatic, attached, continuous (during op. cycle)

5. CREW SUPPORT:
   One crewman, 5 min setup, 30 sec initiation of operation
   Voice annotation desirable
   Number of operation cycles: 100 hours min.; 300 hours desired

6. SPACECRAFT SUPPORT:

Power	- Average	20 watts	
	Peak	28.2 watts	
	Standby	18 watts	
	Total	6 Kwh (300 hours)	
Volume	- ascent	1.43 cu. ft.	no envelope given
	return	0	
Weight	- ascent	40 lbs.	
	return	0	
Data	- analog	5 channels, digital 117 bps (280 nm)	

   Controls - 3 function controls
   Special Requirements - 2400 cycle sync. signal required

7. DEVELOPMENT SCHEDULE:
Approved by MSFEB 10-1-68
Deliver test and training hardware 3-1-70
Deliver flight hardware 10-1-70

8. COST:
Previously funded in FY 1967, 1968
Cost Data: Experiment Equipment

FY 68 300 DEF	FY 69 907K	FY 70 766K
FY 71 173K	FY 72 125K	FY 73 0
500K		

Total Cost: 2.8M

EXPERIMENT DATA SHEET

IR TEMPERATURE SOUNDER - METEOROLOGY/EARTH RESOURCES (S043)

1. SPECIFIC OBJECTIVE: To determine the atmospheric and water vapor vertical profiles with emphasis on high vertical resolution and to measure cloud top or surface temperatures and pursuant cloud cover.

2. GENERAL DESCRIPTION: A modified Ebert grating spectrometer using 15 thermoelectrically cooled PbSe detectors behind slits and order isolation filters appropriately arrayed in the spectral plane to measure the emitted radiation of the atmosphere and the surface in 15 discrete spectral intervals between 3.5μ and 6.0μ. There are also 5 additional detectors in the plane of the grating to measure the radiance in the 4.6μ to 6.0μ region from 5 discrete 0.5°x2.4° elements of the field of view of the spectrometer.

3. OPERATIONAL CONSTRAINTS:
   Altitude - 100-125 nm circular
   Inclination - 50° or 90°
   Time of year - 4th quarter
   Lighting - various sun angles and some dark side targets
   Stabilization- attitude, no more than ± 5° from local vertical
   attitude rate, 0.2°/sec on all areas
   exp. pointing accuracy, must know altitude to ± 1°

4. MODE OF OPERATION:
   Automated
   Attached
   Continuous

5. CREW SUPPORT:
   Number of Operations Cycles: Min Req. 50
   Desired continuous
   Crew:
   Crew activity description: No crewmen 1
   Crew time per cycle: Setup 1 sec - Operation 30 sec - Standby Surveillance as possible
   Skills: Recognition of significant atmospheric phenomena

6. SPACECRAFT SUPPORT:

Weight - 25 lbs.

Volume/Dimensions - 1.25 ft^3 (8"x8"x12")
(9 1/2"x10 1/2"x13")

Power - Average 50W
Peak 60W
Standby 40W
Total (KWH) 20 Kwh

Data - Analog, 1 channel - 30 samples once each 10 sec at 150 sps rate
Digital, 1000 bps in 10-bit words on one channel
Film, from "operational" camera

7. DEVELOPMENT SCHEDULE: Deliver Test Hdw. 4-1-70
Deliver Flight Hdw. 10-1-70

	Phase A	Phase B	Phase C	Phase D
Start	______	______	______	10-1-68
End	______	______	______	11-1-70

8. COST:

Cost Data: Experiment Equipment

FY 68 125K FY 69 310 DEF FY 70 0
FY 71 1330K FY 72 1580K FY 73 620K
FY 74 295K FY 75 280K

Total Cost: 4440K

REVISION PENDING

FUNCTIONAL PROGRAM ELEMENT II

1. DISCIPLINE - Space Applications, Earth Resources and Meteorology

2. PROGRAM ELEMENT - Space Applications Experiments Package - Intermediate Workshop, 1973-75 Flight(s)

3. REQUIREMENT:

The configuration of the First Workshop scientific payload (1970-72) suffers from lack of development time (off-the-shelf), payload weight (500 lbs) and experience in space (feasibility). By 1973, several advanced experiments will have been developed, which will take advantage of low and high flying test aircraft results and unmanned space flight experience and of greater weight, power and time allottments than possible so far. The requirements for the payload are

a. to provide results of operational quality in monitoring activities of man and identifying earth resources, possibly shaking down equipment later to be used for routine operation on unmanned ERTS-ERS user satellites.

b. to further the development of a three-dimensional global weather system.

c. to operate in a manned mode complex, integrated sensing systems in space and provide real-time evaluation and data compaction functions as well as serve as an experimenter and repairman.

4. JUSTIFICATION:

a. To develop and evaluate integrated techniques as shown in the attached Figure 1.

b. To support studies of the Earth's resources by user agencies, especially, to help evolve optimized sensing systems for automated (unmanned) operation.

5. COMPONENT EXPERIMENTS:

In the interest of achieving optimum use of manned missions' capabilities, two space physics experiments described in Space Physics Section (Investigation of Spacecraft In Ion Wake; Cyclotron Harmonic Wave Transmission) should also be

incorporated into the slave satellite required for the radio occulation experiment.

The evolution of all other experiments from the First Workshop payload can be compared using Figure 2. The following experiments are specifically suggested as payload components:

1. advanced metric camera
2. advanced multispectral camera system
3. multichannel infrared scanner/imager
4. radar altimeter/scatterometer
5. passive microwave radiometers
6. microwave imagers
7. radar imager
8. absorption spectrometer
9. advanced short wavelength IR spectrometer
10. IR temperature sounder
11. polarization measurements in the visible
12. stellar refraction density measurements
13. atmospheric density sensing
14. UHF spherics detection

Experiments 5 through 8 are considered critical for earth resources sensing. They have a great potential of useful applications in several user areas as is presently being demonstrated by aircraft testing (see also Nimbus B, E proposals). Therefore, deletion of these experiments until 1975, or exclusively unmanned operation of the same appear unjustified.

6. <u>DESCRIPTION</u>:

The 1973 Intermediate Workshop payload in Space Applications is the first advanced, integrated and specifically designed package of earth resources and meteorological sensors in the manned program. For its development it will take advantage of airborne, unmanned and military experience to date and will represent the first generation of "debugged" non-military sensors in space.

7. <u>SPECIAL CONSIDERATIONS</u>:

a. Orbital inclinations of at least 50° are required for sensing of strong air-mass contrasts.

b. Other special considerations:

Altitude $<$200 miles
Stabilization $< \pm 5°$ (3 sigma)
Altitude rate $\leq 0.05°$/second maximum
High data rate
Film return

c. Radio occultation experiment (remote sensing of atmospheric parameter) involves the employment of an ejected subsatellite and the maintenance of a fixed separation from the manned spacecraft.

FIGURE 1

EARTH RESOURCES

MSF EXPERIMENT PACKAGES FOR MIDDLE TO LATE 1970'S

- All primary earth resources experiments require supporting or secondary experiments in same package.

1. Photographic Package

Multiband Photography Metric/Panoramic Photography Tracking Telescope	Plus Support	IR Radiometer IR Spectrometer IR Interferometer IR Temperature Sounder	and/or	MW Imager Radar or Laser Altimeter MW Radiometers UV Imagers Absorption Spectrometer

2. Imagery Package

Wide-range Spectral Scanner MW Imager UV Imager	Plus Support	IR Radiometer IR Spectrometer IR Interferometer IR Temperature Sounder	and/or	Radar or Laser Altimeter MW Radiometers Radar Imager Absorption Spectrometer

3. Spectral Package

Multiband Photography IR Spectrometer IR Interferometer MW Radiometers Absorption Spectrometer	Plus Support by Photography

4. Surface Properties Package

Wide-range Spectral Scanner MW Radiometer Radar Imager Radio Reflectometer	Plus Support	IR Radiometer IR Spectrometer IR Interferometer IR Temperature Sounder	and/or	MW Imager Radar, Laser Altimeter Radar Imager UV Imager Absorption Spectrometer

5. Atmosphere Package*

Wide-range Scanner
IR Radiometer
IR Spectrometer
IR Interferometer
IR Temperature Sounder
MW Imager
MW Radiometers
UV Imager
Absorptic Spectrometer
UHF Sferics

*Plus Support by Photography

6. Special Studies Package*

Tracking Telescope
Radar Altimeter-Scatterometer
Radio Reflectometer
Radar Imager
Gravity Gradiometer
Magnetometer
UHF Sferics
Dielectric Tape Camera
Day-Night Camera

*Plus Support by Photography

9

FIGURE 2

SPACE EXPERIMENT PROGRAM *

EARTH RESOURCES

FIRST WORKSHOP
1970-1972

TEGORY	SENSOR	REQUIREMENT FOR INCLUSION IN PROGRAM
A	S102 IR Scanner S101 Multiband Photography S100 Metric Camera	Detailed photography and imagery in multispectral mode for recording and analysis for earth resources (scientist - astronauts)
B	S050 IR Temperature Sounder S075 MW Scanner S105 Radar Altimeter Scatterometer S104 MW Radiometer	Use in weather studies strictly unmanned. Use in conjunction with earth resources studies to reduce atmospheric variables (Simultaneity of observation essential).
	S105 Radar Scatterometer S106 Radar Imager	Manned study of sea state, Surface reflectivity, and support.
C	S039 Day/Night camera S040 Dielectric tape camera S103 Short wave spectrometer S049 IR Interferometer S043 IR Spectrometer S106 Radar Imager S049 UHF Sferics	Support and special studies with lower priority - probably not carried in manned missions of early 1970's.

INTERMEDIATE
1973-1975

CATEGORY	SENSOR	REQUIREMENTS FOR INCLUSION IN PROGRAM
A	Multiband photography Metric/panoramic camera Tracking Telescope Wide-Range spectral scanner Radar Altimeter-Scatterometer MW Imager Radar Imager	Detailed photography and imagery in multispectral mode for recording and analysis of earth resources (scientist - astronauts)
B	IR Radiometer IR Spectrometer IR Interferometer IR Temp sounder MW Imager MW Radiometers Radar Imager MW Imager Absorption spec. Radio Reflectometer Laser Altimeter	Use in weather studies unmanned. Use in conjunction with earth resources measurements to reduce atmospheric variables which interfere with signals (simultaneously of observation essential)
	Radar Scatterometer-Altimeter	Manned study of sea state, surface reflect., and support of photography
C	Gravity gradiom. Magnetometer UHF sferics Dielectric tape camera Day/Night Camera	No manned requirements

* These are intended to be sensor packages and not generic lists.

EXPERIMENT DATA SHEET

ADVANCED VERSIONS OF FIRST WORKSHOP(1971) PAYLOADS (LOOK FOR DATA SHEET IN THAT SECTION):

1. Advanced metric camera
2. Advanced multispectral camera system
3. Multichannel IR scanner-imager
4. Advanced short wavelength IR spectrometer
5. Microwave imagers
6. IR temperature sounder*
7. Polarization measurement in the visible*
8. Stellar refraction density measurement*
9. Remote sensing of atmospheric density*
10. UHF sferics*

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*Meteorological section.

EXPERIMENT DATA SHEET

MULTICHANNEL MICROWAVE RADIOMETER - EARTH RESOURCES AND METEOROLOGY

1. SPECIFIC OBJECTIVE: To record the brightness temperature of atmospheric and surface features.

2. GENERAL DESCRIPTION: Several passive microwave radiometers are designed to receive EM energy in several radioastronomy bands and on the shoulders of atmospheric absorption bands in the 5 ghz to 120 ghz region. Each system consists of a receiver, an antenna (fixed), internal calibration (cold and hot sources), data processor and power converters.

3. OPERATIONAL CONSTRAINTS:
   Altitude - no preference, but must be known for design
   Inclination - 50° preferred
   Time of year - 2nd quarter preferred

4. MODE OF OPERATION:
   Automated, attached, intermittent.

5. CREW SUPPORT:
   One crewman, setup 5 min per cycle, 30 sec to initiate operations. Minimum requirement 100 hours, desired 300 hours.

6. SPACECRAFT SUPPORT

Power (est)	- av 100 w
	peak 150 w
	standby 100 w
	total 30 kwh (300 hrs)
Volume (est)	- ascent 7 cu. ft.
	return 0
Weight (est)	- ascent 150 lbs.
	return 0
Data (est)	- analog 5 x 5 channels
	digital 600 bps.

7. DEVELOPMENT SHCEDULE:
   Find system for NASA aircraft to be delivered 9-1-68. Further development unknown.

EXPERIMENT DATA SHEET

ABSORPTION SPECTROMETER - EARTH RESOURCES

1. SPECIFIC OBJECTIVE: To identify spectrally world-wide air pollution and volcanic gases, and to locate lesser concentrations of gases for the tracing of geothermal power and mineral deposits.

2. GENERAL DESCRIPTION: The passive experiment utilizes solar illumination and provides an electrical output directly related to the gas concentration along its telescopic viewing path. Laboratory studies have been made on halogen gases, nitrogen oxide and sulfur dioxide. Flight testing has been performed on SO_2 and NO_2.

3. OPERATIONAL CONSTRAINTS:
   Altitudes - 100 mn to 270 mn acceptable
   Inclination - 50° preferable, 28.5° acceptable
   Solar illumination required
   Test sites within 30° of spacecraft nadir
   Sun angle should be greater than 30° above horizon
   Truth site sampling on the ground may be required.

4. MODE OF OPERATION:
   Automated, attached, intermittent.

5. CREW SUPPORT:
   One crewman, for initiation of sequence.

6. SPACECRAFT SUPPORT:
   Weight - 45 lbs. (does not include imager)
   Power - av. 22 w de
   peak 42 w de
   Volume - 0.90 cu. ft. ascent
   0 descend
   Data - digital, 8 bit words at 50 samples/sec.

7. DEVELOPMENT SCHEDULE:
   Presently in development.

8. COSTS:
   FY 1971 135K, FY 1972 250 K.

EXPERIMENT DATA SHEET

RADAR ALTIMITER SCATTEROMETER, EARTH RESOURCES (S-105)

1. SPECIFIC OBJECTIVE: To provide radar altimeter-scatterometer data of the earth from orbital altitudes for a preliminary study of the earth from space.

2. GENERAL DESCRIPTION: Combined radar altimeter-scatterometer system consists of receiver, transmitter, gating electronics package, and antenna. Initial ground return supplies altitude data. Antenna pattern extends 30° ahead of ground track; return signal supplies scatterometry data.

3. OPERATIONAL CONSTRAINTS:

   Inclination - 28.5° acceptable
   50° desirable
   90° preferred

   Altitude - 100-125 mn preferred
   270 mn acceptable - will require equipment redesign

   Time of year - 1st quarter desirable
   2nd quarter preferred
   3rd quarter acceptable

   Stabilization - attitude, ±1°p, ±2°Y,R
   attitude rate, 0.05P/sec. P,Y,R
   Exp. pointing accuracy ±1°P, ±2°Y,R

4. MODE OF OPERATION:

   automated, attached, continuous over ocean

5. CREW SUPPORT:

   Number of Operations Cycles: min req.-over North Atlantic ocean
   desired-continuous

   Crew: crew activity description: No. crewmen - 1
   crew time per cycle: setup - 15 min.
   operation - 10 min./hr.
   standby - 0

6. SPACECRAFT SUPPORT:

   Weight - Ascent 50 pounds
   Return 0

   Volume/Dimensions- Ascent 19 cubic feet
   Return 0

   Power - Average 80
   Peak 80
   Standby 20
   Total (KWH) TBD - depends upon runtime

   Data - Digital 700 bits/sec.
   Tape uses common data system

7. DEVELOPMENT SCHEDULE:
Approval by MSFEB Oct. 68
Deliver Test & Training Hdw. Oct. 1969
Deliver Flight Hdw. Oct. 1970

	Phase A	Phase B	Phase C	Phase D
Start				Oct. 68
End				Oct. 71

8. COST:
Cost Data: Experiment Equipment FY 68 485K FY 69 905K FY 70 460K
Total Cost: 1.85M FY 71 485K FY 72 905K FY 73 460K
FY 74 200K FY 75 150K

EXPERIMENT DATA SHEET

RADAR IMAGER SYSTEMS, EARTH RESOURCES (S-106)

1. SPECIFIC OBJECTIVE: To provide initial data for the radar studies of the earth from space and to permit basic design of radar for space to be evaluated for future development and design.

2. GENERAL DESCRIPTION: An unfocused synthetic aperature imaging radar; using existing aircraft systems modified for spaceflight, consists of transmitter/receiver, data processor and antenna. Will provide a continuous radar image of a portion of the ground within the antenna pattern. Records data on mangetic tape for data processing and reconstruction of the image using ground facilities.

3. OPERATIONAL CONSTRAINTS:

Inclination - 28.5 acceptable
50° desirable
90° preferred

Altitude - 100-125 nm preferred
270 nm acceptable - requires equipment redesign

Time of Year - 1st quarter desirable
2nd quarter preferred
3rd quarter acceptable

Stabilization - attitude ±1°P,±2°/sec.Y,R
attitude rate 0.05°/sec. P,Y,R
Exp. Pointing accuracy ±1° P, ±2°Y,R

4. MODE OF OPERATION:
automated, attached, intermittent

5. CREW SUPPORT:
Number of Operations Cycles: min. req. 30
desired 30

Crew: Crew Activity description - No. crewmen 1
Crew time per cycle: setup 15 min.
operation 10 min/hr.
standby 0

6. SPACECRAFT SUPPORT:

Weight - Ascent 151 pounds
Return 0

Volume/Dimensions - Ascent 11.5 cu. ft.
Return 0

Power - Average 416 watts
Standby 55 watts
Total (KWH) TBD - depends upon mission

Data - Digital 100 KBS
Tape uses common data system

7. DEVELOPMENT SCHEDULE:
Approval by MSFEB Oct. 68
Deliver Test & Training Hdw. Nov. 69
Deliver Flight Hdw. Nov. 70

	Phase A	Phase B	Phase C	Phase D
Start	____	____	____	Oct. 65
End	____	____	____	Nov. 71

8. COST
Cost Data: Experiment Equipment FY 68 2210K FY 69 2275K FY 70 346K
Total Cost: 4.825 M FY 71 ____ FY 72 ____ FY 73 2210K
FY 74 2275K FY 75 340K FY 76 300K FY 77 200K

FUNCTIONAL PROGRAM ELEMENT III

1. DISCIPLINE:

SPACE APPLICATIONS - Earth Resources and Meteorology

2. PROGRAM ELEMENT: Space Applications Experiments Package - Follow-on Workshop (post-1975)

3. REQUIREMENT:

a. To provide, for the first time, a complete set of all earth resource and meteorological sensing systems for an integrated test for the determination of superior and inferior ways of space sensing, and so as to identify all significant variables to be considered in follow-on operational sensing for user benefits. For some sensors this will be the first test in space; for others, a considerable test history, manned and unmanned, will exist, and correlation with other sensors will be the main objective.

b. To utilize man and his unique capability in selecting optimized user payloads for subsequent (automated) operational missions.

REVISION PENDING

4. JUSTIFICATION:

Many earth resources remote sensing tasks can be accomplished in many different ways. We must know how to do them best, with greatest return to the user, and in optimizing economy and reliability. This will be the justification of the follow-on workshop.

5. COMPONENT EXPERIMENTS:

Metric Camera (Adv. S100)
Multispectral Camera (Adv. S101)
Multichannel scanner-imager
Multi-Frequency dual-polarization radar (Avd. 106)
Radar Altimeter/Scatterometer
Microwave Imager (multi-freq)
Microwave Radiometer (multi-freq)
Absorption Spectrometer and imager
UV Luminescence spectrometer and imager
Laser Altimeter
Long Wavelength Spectrometer
Adv. IR Sounder
Adv. Microwave Sounder
Adv. TV System
Adv. Radio Occultation

All those experiments previously described are not included in the following Experiments Data Sheets which include only new listings.

6. DESCRIPTION:

With the advent of the follow-on workshop, space sensor systems will have come of age. The workshop will provide enough weight capability and support facilities to allow detailed and systematic testing of 1500 to 2000 lbs. of earth looking sensors, which after this mission should be cleared to function in various operational payloads to provide world weather service and user benefits. Also, there will be time and manpower for various specific experiments, taking advantage of the unprecedented integration of coordinated sensor systems which is not possible on unmanned launches.

7. SPECIAL CONSIDERATIONS:

Orbital inclination > 50°
Altitudes < 200 miles (3 sigma)
Stabilization $\leq \pm 5^{\circ}$ Altitude rate $\leq .05^{\circ}$/sec. maximum
High data rate.
Film return

EXPERIMENT DATA SHEET

ADVANCED IMAGING ABSORPTION SPECTROMETER - EARTH RESOURCES

1. SPECIFIC OBJECTIVES: To map the distribution of air pollution and volcanic gases and, possibly, mineralized zones.

2. GENERAL DESCRIPTION: The imaging camera is an advanced absorption spectrometer, using solar illumination and its modification by molecular absorption as a measure of gas concentration.

3. OPERATION CONSTRAINTS:
4. MODE OF OPERATION:
5. CREW SUPPORT:

Same as Absorption Spectrometer

6. SPACECRAFT SUPPORT:
   Weight - 70 lbs.
   Volume - 1.3 cu.ft.
   Power - 50 watts
   Data - three analog channels - continuous operation

7. DEVELOPMENT SCHEDULE: unknown

8. COST: unknown

EXPERIMENT DATA SHEET

UV LUMINESCENCE SPECTROMETER/IMAGER

1. SPECIFIC OBJECTIVE: To identify geoligic features on the earth surface in the UV spectrum, especially reflectivity of surface materials and agricultural and hydrologic studies.

2. GENERAL DESCRIPTION: The UV spectrometer will measure the intensity of emitted and reflected energy as a function of wavelength in selected parts of the UV and visible spectrum where prominent Fraunhofer lines are present. The spectrometer has a special resolution of 0.5A and a scan image of 425A.

3. OPERATIONAL CONSTRAINTS:
Altitude - 100-125 nm preferred
270 nm acceptable
Inclination - 50° preferred
28.5° acceptable
90° not accetpable

Truth sites must be within 30° of spacecraft nadir. Sun angle should be greater than 55° above horizon.Water temperature, dye concentration, atmospheric conditions, must be measured at ground sites during overflight pointing accuracy 1°, unobstructed FOV 15°.

4. MODE OF OPERATION:
Manned, attached, intermittent

5. CREW SUPPORT:
One crewman for initiation of sequence, ground observation and voice annotation.

6. SPACECRAFT SUPPORT:

Power	av 42 w dc
	peak 42 w dc
Volume	3.4 cu. ft. ascent
	0 descent
Weight	150 lbs.
Data	1 channel

7. DEVELOPMENT SCHEDULE:
Prototype operated by USGS
Otherwise unknown

8. COST:
FY 70 1675 FY 71 2900 FY 72 525 FY 73 325
FY 74 353

EXPERIMENT DATA SHEET

LASER ALTIMETER, EARTH RESOURCES

1. SPECIFIC OBJECTIVE: Evaluate the capability of the laser to provide an accurate range measurement to a point on the earth's surface from the spacecraft.

2. GENERAL DESCRIPTION: Range measurement is performed by an elapsed-time-integral computer which is started by the laser output pulse and is stopped by threshold detection of the return signal.

3. OPERATIONAL CONSTRAINTS:
Altitude, inclination, time of year, lighting: none
Stabilization - attitude ±.5°
attitude rate .05/sec.
Exp. Pointing Accuracy 10 sec. of Metric Camera

4. MODE OF OPERATION:
automated, attached, intermittent

5. CREW SUPPORT:
1 crewman, 100 operations cycles desired, crew time - none.

6. SPACECRAFT SUPPORT:

Weight	- ascent 80
	return 0
Volume/Dimension	- ascent 4.8
	return 0
Power	- average 50w
	peak 50w
	standby 20w
	total (KWH) --
Data	- Analog 10 ch.
	Digital 1 ch.

EXPERIMENT DATA SHEET

LONGWAVE IR SPECTROMETER/RADIOMETER (ADV), EARTH RESOURCES

1. SPECIFIC OBJECTIVE: To obtain measurements of emitted radiance in the near-IR spectral range for geologic interpretation, and to use in conjunction with IR widerange images for geologic mapping.

2. GENERAL DESCRIPTION: Instrument consists of off axis reflective telescope, relay optics, and detector/cryogenics unit. Spectrometer operates in 6.5 to 13 μ range and the radiometer in the 10-12 μ range. Resolution is 1/2° - 1° K and spatial resolution is 3.5 milliradians^2. Selected targets of opportunity or preplanned targets within 30° of nadir are sensed.

3. OPERATIONAL CONSTRAINTS:

Inclination	>35° preferred, circular
Altitude	>200 nm
Time of Year	2nd and 3rd quarters preferred
Viewing direction	within 30° of nadir
Stabilization	attitude - not required attitude rate ± 0.1°/sec. Exp. Pointing Accuracy ± 3° of command attitude.

4. MODE OF OPERATION:
automated or manned, attached, intermittent

5. CREW SUPPORT:
Number of Operations Cycles: min. req. - 7 min. twice per day
desired - as available
Crew: Crew Activity description: no. crewmen - 1

Skills: equipment operation, target identification, description, selection

6. SPACECRAFT SUPPORT:

Weight	- Ascent 65 lbs. Return 0
Volume/Dimensions	- Ascent 25"x12"x22" plus 3"x6"x10" Return 0
Power	- Average 65w Peak 55w Standby 50w Total (KWH) according to schedule
Data	- Analog - 2 channels, 0.1% accuracy, 1900 sample/sec., 10 bit words

7. DEVELOPMENT SCHEDULE:

Unknown

8. COST:

Experiment Equipment	FY 68 ____	FY 69 ____	FY 70 775K
Total Cost: 3035	FY 71 1525	FY 72 2223	FY 73 415
	FY 74 100K		

FUNCTIONAL PROGRAM ELEMENT IV

1. DISCIPLINE - Space Applications - Meteorology

2. PROGRAM ELEMENT - Space Applications Experiments Package - (Meteorology), (Sub-Satellite Experiments), 1973-75 Flights.

3. REQUIREMENT:

By the mid-70's IR radiometers flown on the First Workshop and in the Nimbus Program will have demonstrated the capability to measure atmosphere temperature and water vapor profiles under favorable cloud conditions. Initial efforts to measure these parameters by microwave radiometers will be made. However the essential atmospheric parameter needed for global numerical long range weather prediction, density, cannot be determined from the temperature profile unless one pressure point in the vertical profile is known. To obtain this pressure point on a global basis is an impossible logistic problem from surface stations and an instrument miniaturization and development problem of great difficulty because of FAA regulations if the measurement is made from constant level balloons. Therefore experiments to measure atmospheric density directly are of the highest priority. This experiment package contains two density experiments, Atmospheric Density by Radio Occultation, and Stellar Refraction Density Measurement. The latter is susceptible to cloud interference; primary reliance must be placed on the Radio Occultation experiment. It appears probable that an independent measure of water vapor is needed to support this experiment; hence, it must be supported by IR and microwave radiometer experiments.

4. JUSTIFICATION:

a. To test the feasibility of sensing systems to directly determine the global atmospheric density profile-the prime data needed for long range global weather prediction.

b. By supporting instruments support the atmospheric density experiment and provide other required atmospheric data and lower boundary data needed for long range global weather prediction.

5. COMPONENT EXPERIMENTS:

The core experiment is the Radio Occulation Atmospheric Density experiment. It must be supported by IR and microwave radiometer experiments. Other meteorology experiments are included including the correlative Stellar Refraction Density Measurements experiment.

The Atmospheric Density Radio Occulation experiment requires a slave satellite. In the interest of achieving optimum use of manned missions' capabilities two space physics experiments (Investigation of Spacecraft Ion Wake; Cyclotron Hamionic Wave Transmission) are also carried on the slave satellite. The slave satellite must be maneuverable. Certain electronic components on the slave satellite can be shared by the atmospheric experiments and the space physics experiments as the experiments will not be conducted simultaneously.

The following experiments are specifically suggested as payload components:

1. advanced metric camera
2. advanced multispectral camera system
3. multichannel infrared scanner/imager
4. radar altimeter/scatterometer
5. passive microwave radiometers
6. microwave imagers
7. radar imager
8. absorption spectrometer
9. advanced short wavelength IR spectrometer
10. IR sounder
11. polarization measurements in the visible
12. stellar refraction density measurements
13. atmospheric density by radio occultation
14. UHF spherics detection

Experiments 5, 10, 12, 13 are the core meteorological experiments. Experiments 11 and 14 are also important meteorological experiments. The other, earth resources, experiments support meteorology by providing data on the lower boundary of the atmosphere.

6. DESCRIPTION:

The 1973 Intermediate Workshop payload in Space Applications is the first advanced, integrated and specifically designed package of earth resources and meteorological sensors in the manned program. It will include the first flight of a meteorological experiment of the highest priority. For its development it will take advantage of airborne, unmanned and and military experience to date and will represent the first generation of "debugged" non-military sensors in space.

7. SPECIAL CONSIDERATIONS:

a. Orbital inclinations of at least 50° are required for sensing of strong air-mass contrasts.

b. Other special considerations:

Altitude <200 miles
Stabilization $< \pm 5°$ (3 sigma)

Altitude rate $<0.05°$/second maximum
High data rate
Film return

c. Radio occultation experiment (remote sensing of atmospheric density) involves the employment of an ejected subsatellite and the maintenance of planned separation distances from the manned spacecraft.

EXPERIMENT DATA SHEET

VISIBLE RADIATION POLARIZATION MEASUREMENTS, METEOROLOGY (S-046)

1. SPECIFIC OBJECTIVE: To measure the Stokes parameters of the visible region radiation emerging from the top of the atmosphere in order to a) study the effects of the surface reflection on such radiation, and b) to attempt to determine the vertical distribution of atmospheric aerosol.

2. GENERAL DESCRIPTION: The experiment package consists of a light sensing package; collimator tubes, polarizers oriented in specific directions, interference filters, photomultiplier tubes; and an electronics module. Four relatively narrow spectral regions (bandwidth 100 to 150Å) will be studied, centered at approximately 3800 Å, 4400 Å, 5000 Å, and 5800 Å. Four identical polarizers will be used to transmit components at angles of 0°, 45°, 90°, and 135°. The field of view for each of the four collimators is 3°.

3. OPERATIONAL CONSTRAINTS:

Inclination	- 45-90° preferred, 35° acceptable
Altitude	- 100-200NM preferred, <400NM acceptable
Eccentricity	- circular orbit
Time of year	- no seasonal requirements
Lighting	- sun angle >10°. 10 different sun angles for each target desirable.
Stabilization	- local vertical not required LOS maintenance within ±.5° of commanded attitude LOS rates maintained within 0.2°/sec of the commanded rates

4. MODE OF OPERATION:

Manned, attached, intermittent

5. CREW SUPPORT:

Number of Operations Cycle: 100 (10 types of targets at 10 different sun angles)

Crew - 1 man
Crew time per cycle

Set up/warm up	Select, identify, acquire target	Switch to scan, describe target
30 min*	2 min.	2 min.

*full attention of crewman not required for 30 minutes.

6. SPACECRAFT SUPPORT:

Weight - 25 lbs. - return negligible

Volume - 1.3 ft^3

Envelope - 10" x 18" x 10" plus 10" x 4" x 10"

Power - 50w peak; 15w avg., standby 1w

Data - 16 analog data channels 10 bits/sec/ea
housekeeping 16 bits/sec
voice and time annotation required
back up photography required

7. DEVELOPMENT SCHEDULE:

In Phase B or C: 2 years until launch

8. COST:

∿$1 M

EXPERIMENT DATA SHEET

STELLAR REFRACTION DENSITY MEASUREMENTS - METEOROLOGY (S047)

1. SPECIFIC OBJECTIVE: To globally measure the three dimensional profile of atmospheric density by refraction of starlight by the atmosphere.

2. GENERAL DESCRIPTION: The instrument elements consist of an acquisition star-tracking telescope, a data star-tracking telescope, an azimuth gyroscope and an elevation gyroscope. The refraction of light from a star is related to the time rate of change of the position of the star as the earth's atmosphere occults it as the spacecraft moves in its orbit.

3. OPERATIONAL CONSTRAINTS:

Altitude	- 100-300NM
Inclination	- >45° preferred, >30° acceptable
Eccentricity	- no requirement for circular orbit
Time of day	- operable only at night
Sun	- no exposure to sunlight
Stabilization	- no requirement for local vertical LOS orientation maintained within ±0.5° of commanded altitude LOS rates maintained within .05 deg/sec of commanded rates

4. MODE OF OPERATION:

Manned, attached, interrmittent
Man selects targets, acquires targets, maintains spac. .'aft on target line while tracking.

5. CREW SUPPORT:

One crewman, 30 min. set up, 40 min operation each cycle, 10-15 cycles at 1 cycle per day required.

(1) Set up	(2) Visual acquisition of targets 3 min. ea. x 4obs./cycle	(3) Switch to auto	(4) Auto track 5 min. ea. x 4 obs./cycle
~30 min*	12 min	2 min	20 min

*full attention of astronaut not required for 30 min.

6. SPACECRAFT SUPPORT:

Power - Peak 104w, average 65w

Weight - 110 lbs. Return weight zero

Volume - 4 ft^3

Envelope - 42" x 12" x 18"

Data - ∿900 bits/sec x 400 min. (tape recorded) voice annotation and star field photography required

7. DEVELOPMENT SCHEDULE:

8. COST:

∿$2 M

EXPERIMENT DATA SHEET

UHF SPHERICS - METEOROLOGY (S-048)

1. SPECIFIC OBJECTIVE: To detect thunderstorm connected atmospheric electrical activity in order to

   a. map the global distribution of thunderstorm activity

   b. help to identify weather phenomena

   c. test the theory that thunderstorms maintain the earth-ionosphere potential difference.

2. GENERAL DESCRIPTION: Instrument consists of an antenna system, a low-noise UHF receiver, and a data processing and storage unit. UHF signals emitted by atmospheric phenomena are directionaly received and recorded.

3. OPERATIONAL CONSTRAINTS:

Altitude	- 100-200NM preferred; <300NM acceptable
Inclination	- >50° preferred; >30° acceptable
Eccentricity	- circular orbit
Time of year	- summer or winter
Lighting	- no sun angle or lighting requirements
Stabilization	- LOS ±2.0°
	LOS rate ±0.5°/sec
	Local vertical maintained 90% of time
	Maneuvers to acquire off track targets desirable

4. MODE OF OPERATION:
   Attached
   Mode 1: manned/intermittent
   Mode 2: automated/continuous

5. CREW SUPPORT:
   Manned mode (special target) 12-20 cycles
   Automated mode - continuous

   Crew activity description (manned mode)
   One crewman required
   Crew time per cycle:

Visually acquire target of interest	Maneuver to point antenna at target	Describe target and actuate event (lightning) markers photograph target
3 min.	2 min.	2 min.

   Skill: recognize meteorological phenomena likely to emit UHF energy.

6. <u>SPACECRAFT SUPPORT</u>:

Weight - 35 lbs. no return

Volume - 2100 in^3

Envelope - 48"D x 5" plus 9" x 9" x 6" plus 8" x 10" x 5"

Power - 6w

Data - Digital: 320 b/s
Analog: 8 channels, 0.1 s/sec

7. <u>DEVELOPMENT SCHEDULE</u>:

Phase B or C?
18 months to flight.

8. <u>COST</u>:

∿1.25M

REVISION PENDING

FUNCTIONAL PROGRAM ELEMENT V

1. DISCIPLINE - Space Applications - Meteorology
(Follow-on Workshop - Post 1975)

2. PROGRAM ELEMENT - Advanced Atmospheric Sensing System (advanced atmospheric density by radio occultation experiment and supporting/correlative experiments)

3. REQUIREMENT:

a. Demonstrate a meteorological sensing system that will provide the global three-dimensional atmospheric data and the lower boundary (earth's surface) data required for developing long range weather prediction numerical models.

b. Examine the specific aspects of man's capability in support of such a system.

4. JUSTIFICATION:

a. The earlier flight of the Atmospheric Density by Radio Occultation experiment will have demonstrated the capability of this method to provide the prime atmospheric data (density) required for long range numerical weather prediction. The application of this method to provide density data with the required vertical and horizontal resolution will require a system with four to six slave satellites. Each slave satellite must have a long duration capability including a power system and propulsion system for station keeping.

The status of numerical weather prediction will have advanced to the state where in addition to the density and temperature field the state and distribution of water in the atmosphere and the condition of the lower boundary will be included in the models. Thus data from earth resources experiments will be used in addition to atmospheric data from the meteorological sensors.

b. Man's ability to operate and functionally support a major earth looking observatory will be evaluated and demonstrated. Crew members will function in these areas:

1) maintenance and repair

2) checkout, calibration, adjustment, refurbishment

3) provide flexibility in sensing operations as required

4) observation

5. COMPONENT EXPERIMENTS:

1. Advanced Atmospheric Density by Radio Occultation
2. Advanced IR Sounder
3. Advanced Microwave Radiometer
4. Advanced Visual Imager
5. Advanced IR Imager/Radiometer
6. Advanced Passive Microwave Imager
7. Radar Scatterometer
8. Other Earth Surface Sensors

6. DESCRIPTION:

The mission dominating experiment is the Advanced Atmospheric Density by Radio Occultation experiment. Four to six slave satellites, each approximately 2.5-3.0 feet in diameter and weighing 250-300 lbs., will be carried into orbit and deployed. Master-slave separation must be established and maintained such that the atmosphere is sampled at 4-6 different altitudes. Provision for "collecting" the slaves and replenishing their propulsion fuel and other checking may be desirable. The equipment on the space station must either be more extensive or much more sophisticated than in the first experiment in order to operate with and control a number of slave satellites.

The other correlative/supporting experiments are described in other program elements for this flight.

7. SPECIAL CONSIDERATIONS:

Orbital inclination >50°
Altitudes <200 miles (3 sigma)
Stabilization ≤ ±.5° Altitude rate ≤ .05°/sec. maximum

High data rate
Film return
Launch, control, logistic support to slave satellites

EXPERIMENT DATA SHEET

ATMOSPHERIC DENSITY BY RADIO OCCULTATION - METEOROLOGY

1. SPECIFIC OBJECTIVE: To measure the vertical profile of atmospheric density and its horizontal gradient.

2. GENERAL DESCRIPTION: A small spin-stabilized satellite is ejected from a master space station and the master station is maneuvered such that the line of sight between them intersects the atmosphere at varying altitude. Prior to positioning for this experiment, and after detachment from master, maneuvering is done for space physics experiments. Atmospheric density of an acceptably small region around the closest point of approach of the line of sight to the earth's surface is proportional to the amount by which a 5GHz signal is refracted in passing from the master to the slave and back. Basic elements of the slave satellite system are a phase locked ranging transponder, power supply and antenna. Basic elements on the master are a standard frequency oscillator and transmitter, parabolic antenna, range code generator, and phase locked receiver. Station keeping propulsion capability is required in the master station.

3. OPERATIONAL CONSTRAINTS:

   Orbit - circular
   Inclination - >40°
   Altitude - <300 NM

   Accurate measure of true distance between master and slave satellite is required
   Independent measure of atmospheric water vapor is required
   Time of year - 1st or 4th quarter

4. MODE OF OPERATION

   Manned (deployment and station keeping) automatic during data taking
   Detached
   Intermittent

5. CREW SUPPORT:
   Launch of slave satellite (15-20 min)
   Station keeping, operation (total 100 min)

6. SPACECRAFT SUPPORT:

   A. Master system: Weight - 22 lbs.
   Volume - 1000 in^3
   plus antenna 24" D x 6"
   Power - 24 w
   Antenna stabilized and directed to slave satellite

Controls and display - 2 controls
3 function display
Data - 3 Analog channels - 4 kHz
1Hz
100 - 500Hz

B. Slave satellite system:
Weight - 200 lbs. (including space physics experiments)
Volume - ~2 ft^3 (including space physics experiments)
Power - 240w(self contained batteries or solar cell system)

7. DEVELOPMENT SCHEDULE:

Proposal - Phase A-C?
Begin - Phase D 11/68
Deliver flight hardware 11/71

8. COST:

'69 '70 '71 '72 '73 '74

Total cost ~5-8M dollars including space physics experiments.

FUNCTIONAL PROGRAM ELEMENT VI

PLANNING PANEL ON COMMUNICATIONS & NAVIGATION
MANNED MISSION EXPERIMENTS SUBPROGRAM

1. INTRODUCTION

In the preceding sections of this report, planned studies, experiments and missions have been discussed in terms of unmanned or automated space flight missions. This section of the report will cover those experiments and other activities, in all five discipline areas, for which the presence of man is either helpful or essential.

The subject of Space Applications flight experiments on manned missions has been under consideration for several years, ever since the beginning of the Apollo Applications Program. A number of experiments were proposed in the communications and navigation areas, and several studies were conducted to determine the feasibility of these experiments in more detail. The number and kind of experiments considered feasible for manned missions will be influenced by the mission parameters, and these in turn will be influenced by experiment requirements and available ground support. Therefore, an appropriate introduction to a discussion of the proposed experiments is a brief outline of the proposed manned program as it now stands.

This proposed program has three principal components:

1. Two "dry workshop" (DWS) missions, in 1972 and 1974, both at 35 degrees inclination and 260 nautical miles altitude. These dry workshops consist of a Saturn IV-B, without engines or fuel tanks, which has been fitted out for one month man-occupancy, together with a Multiple Docking Adapter, an Apollo Telescope Mount and a Command and Service Module. It is planned that each of these will remain in orbit for 18 months, during which time four or more one-month manned-missions would be carried out.

2. A Modular Space Station launched in 1975 into a 55 degree orbit at about 260 nautical miles altitude. The first Module would be flown in 1975 followed by additional Modules until the space station is complete.

3. A synchronous altitude manned mission to be flown sometime in the late 1970's.

Applications experiments for the proposed Manned Space Flight program were considered by the Science, Applications and Technology (SA&T) Subpanel of the Planning Panel on Earth Orbiting Manned Space Flight (EOMSF). Certain members of the Planning Panel on Communications and

Navigation met with the Chairman of this Subpanel on July 15, 1969, and the proposals offered later in this section reflect the discussion at that meeting.

2. PROGRAM GOALS AND OBJECTIVES

a. Goal

The goals and objectives of the manned mission experiments subprogram are of course the same as the goals and objectives of the discipline subprograms from which they are drawn. Another goal is to make maximum use of the unique capabilities of man in space in attaining the discipline goals and objectives.

3. PROGRAM JUSTIFICATION

Justification for the manned mission experiments subprogram derives from the justifications stated under the five discipline subprograms treated previously in this report. In addition, each of the program elements discussed below includes a justification or rationale for a manned-approach either in addition to, or in lieu of, an automated approach.

4. PROGRAM DESCRIPTION

The Science, Applications and Technology Subpanel (SA&T) of the EOMSF Planning Panel proposed several experiments, beginning in 1975, for the Space Station Module and for the later Synchronous Altitude Manned Mission. These proposals were discussed at the aforementioned meeting on July 15 at which general agreement was reached on the program elements discussed below. Among other things, it was agreed that experiments for dry workshops, numbers 1 and 2 would be proposed within the time and other constraints applicable to these missions.

For the sake of clarity and understanding, the following proposals are presented in terms of the manned missions rather than in terms of the separate disciplines involved.

a. Dry Workshops Nos. 1 & 2

An essential ingredient of experiment proposals for these dry workshops is the probability that ATS-F and ATS-G will be in orbit and operating in the same time-frame. Therefore, two of the three experiments proposed for dry workshops are cooperative with ATS-F and/or G. These are (1) range and range-rate measurements at X-band using ATS transponders (or ATS-type transponders at ground stations), and (2) wide-band data relay

from the dry workshop to the ground via ATS-F or G. These experiments are described in more detail in the experiment data sheets appended to this section.

The third experiment category applicable to the dry workshops is measurement of radio frequency interference in one or more radio frequency bands employed for Earth-space communications and data. (It was agreed, at the aforementioned July 15 meeting, that propagation experiments and radio frequency experiments should be considered for each and every manned mission, as these experiments are characterized by the need for data over long periods to provide a valid and satisfactory statistical base.)

The feasibility of making radio frequency interference (RFI) measurements from a low altitude manned spacecraft was studied by General Dynamics CONVAIR as part of the earlier Apollo Applications program. The principal conclusions and recommendations of that study are appended to this section.

The principal shortcoming of an RFI experiment at low orbit altitudes is the small percentage of time that any given area is within the horizon of the satellite. For a 200 nautical mile circular orbit, for example, observation time for a particular area is on the order of the one percent: however, these samples are random with time. An in-house study will be undertaken in FY 1970 to assess the value of RFI experiments as a function of percent observation time, as a basis for deciding whether or not this type of experiment is cost-beneficial for low altitude orbits such as DWS and Space Station orbits.

The rationale and justification for including wide-band data relay experiments, and range and range-rate experiments on the DWS is that t missions will probably be the principal source of wide-band data with n to test and evaluate data relay concepts and configurations, and that manned missions provide an enhanced opportunity to compare actual satellite positions with those positions indicated by range and range-rate measurements.

The rationale and justification for manned RFI experiments, developed in the aforementioned GD-C study, is summarized below:

"... The astronaut could merely turn the Orbiting Spectrum Measurement Experiment (OSME) on and perform similar trivial operations. However, man-in-the-link to evaluate the data, make decisions, and to modify the experiment is most difficult if not impossible to duplicate with technology. For the first experiment, the participation of man will greatly enhance the OSME. The operations which the astronaut may perform are summarized as:

1. Astronaut steers spacecraft or antennas to lock-on specific desired targets during overflight to achieve accurate frequency-vs.-displacement profiles of targets.

2. Astronaut aligns and maintains spacecraft or antennas in appropriate azimuth and elevation orientations with respect to ground track during those periods of time required to cover desired land areas.

3. Data selectivity can be performed by astronaut monitoring and judging the experiment output as displayed.

4. Astronaut monitors intentionally varied ground transmitter emissions for real time voice feedback to ground experimenters.

5. Astronaut performs frequency and amplitude calibration."

FY-1971 funding requirements for these experiments are estimated at $5 million:

- $1 Million for range and range-rate equipment;
- $2 million to implement the wideband data relay experiment;
- $2 million (per GD-C estimate) for a radio frequency interference experiment.

b. Space Station, Modular

The following opportunities are foreseen for communications and navigation experiments in the Modular space station:

1. Continuation and expansion of data relay and position fixing experiments, and possible quasi-operational use of these facilities,

2. Additional RFI experiments at selected frequencies, depending on the intrinsic feasibility of these experiments at low altitudes and on the results of previous experiments with the DWS.

3. Space-erectable structures, primarily antennas, the erection and performance of which can be monitored and reported on by astronauts.

4. Millimeter-wave propagation and communication experiments, space-to-space and space-to-earth, the latter dependent upon re-evaluation of the sampling problem (see discussion of sampling time for RFI experiments under Dry Work Shops, above).

5. Satellite-borne radio interferometer for position fixing purposes.

Justification for the first two of these opportunities has already been discussed under the DWS.

The use of man to observe and possibly even participate in erection of structures in space is of obvious value, and could obviate the need for most if not all of the complex and costly instrumentation needed to monitor such experiments on automated spacecraft.

Man's contribution to millimeter-wave experiments is to observe and adjust space borne equipment, and to return experiment data records to earth. The latter becomes especially significant at very short wave lengths, where power and other limitations necessitate the energy source be ground-based, with the receivers in the spacecraft. Previous experience with recording and relaying data of this kind indicates that results would be improved by recording the data directly at the spacecraft and returning the records physically to earth. This justification applies also to the radio interferometer, in that an astronaut can observe boom deployment, photograph boom fluctuations, vary boom lengths, and change interferometer antennas.

DWS Experiment Data Sheets on range and range-rate, wideband data relay and RFI apply also to Space Station experiments. Data sheets on the millimeter-wave and interferometer are included at the end of this Section.

Funds in the amount of 1.5 million should be budgeted in FY 1971 to perform experiment definition studies in some or all of the areas outlined above.

It should be noted, in concluding this discussion of low-altitude manned platforms, that a major consideration affecting their utility for space applications experiments is orientation. For solar and stellar telescope observations, these platforms will be inertially oriented. They will also be capable of earth orientation for applications experiments, expecially while unmanned; but is not yet clear how long such earth orientation can be sustained.

c. Synchronous Manned Mission

The experiment categories for a synchronous mission are essentially the same as those stated for the Space Station Module, although the experiment configurations for synchronous altitude may differ considerably from those for low altitude missions.

An additional experiment opportunity for geosynchronous missions is for demonstrating broadcast satellite technology. Such experiments necessitate a synchronous or near-synchronous mission (1) to facilitate the use

of fixed, directional receiving antennas; (2) because the experiment power and weight requirement places it in the Saturn V hardware class; and (3) because the presence of man will be beneficial in monitoring and adjusting the equipment.

Communications and navigation experiments for a synchronous mission have not yet been studied in any detail and therefore cannot be described at this time. However, since a synchronous orbit manned space station is not foreseen before CY 1978 or 1979, these experiment opportunities will be studied in-house during FY 1970 and more details will be provided in the FY 1972 planning documentation. No substantial funding requirements are anticipated prior to FY 1973.

EXPERIMENT DATA SHEET

RANGE AND RANGE-RATE MEASUREMENT

1. SPECIFIC OBJECTIVE

Acquire critical data on VHF, microwave, and millimeter wave propagation in the atmosphere as it affects accuracy of range and range-rate measurements.

2. GENERAL DESCRIPTION

The basic technique will be to perform measurements of the apparent range and range-rate of the spacecraft with respect to a series of simple, portable ground stations using a variety of carrier frequencies. The Doppler frequency shifts used to measure the range-rate will not be contaminated by the tropospheric refraction effects that complicate measurements on the ground. The only correction necessary to compute exact relative velocities from the Doppler data will be the correction for local electron density. This can be obtained either from the frequency dependence of the Doppler shift or from direct measurements with a probe mounted on the antenna.

The apparent range, on the other hand, will contain a contribution due to the retardation of the radio waves in passing through the total atmosphere. If a series of measurements are made while passing over a ground station, the true range as a function of time can be determined (except for an additive constant which is not needed for the purposes of this experiment) by integrating the range-rate data obtained from the Doppler measurements. This knowledge of the variation of the true range can be used to extract the changes due to ionospheric and atmospheric effects from the measurements of apparent range. If data are also taken on the average electron density in the ionospheric (see Data Sheet on Ionosphere Electron Density Mapping), then the ionospheric and tropospheric effects can be separated.

This experiment would also demonstrate the feasibility of determining the workshop's orbit with an on-board range and range-rate tracking system, and would provide data on the accuracy and operational problems of the method.

The experiment would employ the high-gain tracking antenna used for the ATS relay experiment. Additional required equipment would be an electronic system for range and range-rate measurements, a data recording system, and a set of transponder packages placed at various locations on the ground.

A variety of frequencies should be used: preferably UHF, S-band, C-band and X-band. Range and range-rate systems and transponders have been developed to work in all of these bands. Thus, the ground transponder packages could consist partly of existing hardware, although larger power amplifiers would be desirable.

Data would be taken over a variety of geographical and meteorological conditions. Initially, the emphasis would be on defining the phenomena that occur in the fine structure of atmospheric radio refraction. Later studies would seek correlations between the radio refraction effects and other effects, such as solar activity and atmospheric circulation, to aid in the formation of descriptive and predictive theories.

3. OPERATIONAL CONSTRAINTS

The experiment would be best performed from an orbit above the F_2 maximum in the ionosphere, which occurs at about 200 NM altitude.

Stabilization and pointing requirements would depend on the capabilities of the tracking antenna system, but should not be severe. For an initial survey of the phenomena, orbital inclination would not be critical. Moreover, a low-inclination orbit would cover most of the part of the world where satellite telecommunications are expected to be most necessary.

4. MODE OF OPERATION

All equipment except the tracking antenna would be inside the spacecraft, and data-taking on any given pass would be automated.

Data-taking runs would be intermittent and largely dictated by the availability of the tracking antenna, scheduling electrical loads, and timing of passages over ground terminals.

After an initial survey of the ground network to define geographical and diurnal effects, runs of the experiment would be scheduled to make observations under special weather conditions and to compile data over portable stations each time they were moved.

5. CREW SUPPORT

Crew functions would comprise managing the experiment to meet scheduling requirements and make best use of spacecraft resources; servicing the equipment; and operational functions such as setting up and initiating runs of the experiment. Crew members must understand the experiment well enough to participate intelligently in decisions on experiment management and must be able to maintain the equipment. Skills needed for operation will be minimal.

6. SPACECRAFT SUPPORT

Equipment specifically for this experiment will be a rack-mounted electronics package:

Volume - 1 to 2 cubic feet
Weight - 50 to 80 lb.
Power - about 100 watts

EXPERIMENT DATA SHEET

DWS/ATS WIDEBAND TELEVISION AND TRACKING RELAY

1. SPECIFIC OBJECTIVE:

Develop means of communicating between orbiting spacecraft and ground via synchronous satellite relay.

2. GENERAL DESCRIPTION:

The major experiment components on the workshop will be a high gain (27 to 33 dB) tracking antenna, a coherent range and range-rate transponder operating on the ATS X band tracking frequencies, a receiver and transmitter operating on the ATS S band user frequencies, and power amplifiers sized for operation at synchronous satellite ranges (20 to 50 watts).

Other major requirements are that the ATS-F or G satellite should be operating at the time of the experiment and that proper interface equipment should be provided between an ATS ground station and the Manned Space Flight Network. The experiment will consist essentially of two parts:

a. Tracking the workshop from a single ground station by measuring range and range-rate with respect to the ATS satellite and using the latter to relay the information to the ground. Since the position of the ATS with respect to the ground station is known independently, the position of the spacecraft can be determined.

b. Wideband data transmission via the ATS satellite's frequency translation repeater. Available bandwidth will be largely determined by the quality of the workshop and ATS antennas, but with 33 dB antenna gain at the workshop, bandwidths in excess of 5 MHz should be achievable. Real-time TV could be transmitted, but the essential part of the experiment would be to transmit "test pattern" signals at various bandwidths and signal strengths to evaluate the limits of system performance.

Successful performance of both parts of the experiment will demonstrate the feasibility of supporting future manned and automated orbital operations with a single ground control center and a set of synchronous data relay satellites.

3. <u>OPERATIONAL CONSTRAINTS</u>:

The only fundamental requirements are that the experiment must fly at a time when an appropriately equipped ATS satellite is available, and that the antenna pointing system should be able to track the ATS whenever it is in view. The antenna should be able to track the direction of the ATS with $\pm$ 1/2^{o} accuracy in the presence of orbital motion of the spacecraft and functioning of the attitude control system.

4. <u>MODE OF OPERATION</u>:

a. Tracking experiments will be automated except for initiation by the crew. The ATS satellite will be available for half of each orbit, and tracking should be continued in each run of the experiment until the system's limits for refinement of the orbit determination are reached. Data recording and analysis will all be performed on the ground.

b. Wideband transmission experiments will require setup by the crew and crew support with real time space-to-ground communication for management of test sequences. Presumably some TV coverage of events in the spacecraft will be desired. Operating time will occur in blocks equal to half the orbital period. Most of the transmissions will be from space-to-ground, and recorded on the ground.

5. <u>CREW SUPPORT</u>:

a. Tracking tests will require only initiation and monitoring of equipment function. Possibly it will be desirable for a crew member to switch the equipment to "standby" condition in dead parts of the orbit to save power.

b. Wideband transmission tests will require a crewman to switch signal generators, vary power levels, etc., on request from the ground, record received transmissions, and possibly play back pre-recorded tapes. TV transmissions will require setup and operation of a camera, and at least some of the subject matter and scheduling should be left to the discretion of the crew.

In both cases, the operating crew member should be skilled in electronics and specially instructed in the details of the relay system.

Astronaut duty cycle during the tests will be made up of time blocks equal to half the orbital period. Tracking tests will require little attention and, once started, should continue for several orbits at a time.

Wideband transmission tests can be broken up quite arbitrarily to fit overall scheduling requirements. Technical testing of the wideband transmission link will take about four hours. Time devoted to transmission of TV or other information should be left free, within wide limits, to be decided during the mission.

6. SPACECRAFT SUPPORT:

a. Antenna - Nominal 10 feet diameter, must be mounted on outside of spacecraft in such a way that it can track independent of spacecraft motion. Weight may be 100-150 pounds if a rigid type is used, 75-100 pound if deployable. A rigid type is preferable because its gain will be higher and it will be more reliable than a deployable antenna.

Power requirement of the pointing system would be about 100 watts. Assuming that the feed mask could be folded against the dish in the stowed configuration,the antenna would fill a 10 ft. dia x 2 ft. high package and its support (included in the above weight estimates) would occupy about 1.5 to 2 cu. ft.

b. Electronics - Tracking experiment transponder would be roughly 200 in^3,15 lb., and consume about 30 watts.

Wideband data transmitter would be about the same as above; signal generators will be about 100 in^3, 8 lb., 10 watts.

Power amplifiers will be about 800 in^3, 30 or 40 lb., 80 to 150 watts.

Overall electronics package requirements will therefore come to about:

Volume - 1 cu. ft.

Weight - 60 to 80 lbs.

Power - 150 to 200 watts.

EXPERIMENT DATA SHEET

RADIO FREQUENCY INTERFERENCE EXPERIMENT

1. SPECIFIC OBJECTIVE:

Map radio interference from ground and space broadcast sources

2. GENERAL DESCRIPTION:

The essential purpose of this experiment is to exploit the capabilities of the high-gain antenna provided for the ATS Relay experiment at times when it is not required for other purposes. During these periods the antenna would be kept pointed at either the spacecraft Zenith or Nadir, and signal levels in the various communications bands (VHF, UHF, S-, C-, and X-band) would be monitored and recorded. Because of the narrow beam width of the antenna (3^o at S-band frequencies), the data would make up a radio interference map with relatively high resolution.

Data obtained from the Nadir direction would be of value in analyzing interference problems affecting radio frequency utilization by the ATS satellites, and would be of greater value in planning more advanced systems. Data from the Zenith direction would provide a much more complete picture of the antenna patterns of the current synchronous satellites than has hitherto been available. Since atmospheric attenuation would be avoided, the experiment might also contribute some useful knowledge about weak celestial radio sources.

Apparatus specifically required for this experiment would comprise an electronic system for measuring signal levels in a selected series of frequency bands, and facilities for recording the data as functions of spacecraft position.

3. OPERATIONAL CONSTRAINTS:

The experiment would be most useful if it were performed at an altitude above the F_2 ionosphere maximum, so that terrestrial and celestial sources could be distinguished with a minimum amount of interpretation. A high-inclination orbit would increase the value of the earth-looking data because it would take in areas of dense communications traffic. However, a low inclination orbit would produce data which do not presently exist for the area that would be covered.

The completeness of space-looking data would not be much affected by orbital inclination because the synchronous satellites are all located above the earth's Equator. Moreover, if the experiment proved to give highly interesting results on celestial sources the parts of the celestial sphere outside the orbit's limiting altitudes could be covered by using the antenna's tracking mechanism.

Electronic power requirements for the interference mapping experiment would be minimized by running it during periods when the workshop was to be flown in a fixed altitude with respect to earth. However, if the ATS Relay antenna can track a synchronous satellite it will also be able to track either the Zenith or Nadir direction with minimal requirements on spacecraft orientation.

4. MODE OF OPERATION:

The experiment will be purely automated, requiring only management decisions and maintenance from the crew. Operation will be intermittent, during periods when the antenna is not otherwise engaged. Periods of operation should include several orbits at a time so that the data from each run will cover a large area of the earth or celestial sphere.

5. CREW SUPPORT:

Crew activities will comprise setting up the proper system configuration for each run, routine checking on the system's operation, and maintenance as required.

6. SPACECRAFT SUPPORT:

Electronic package will come to about 300 cu. in., 5 lb., and 20 watts. Access will be needed to a recording system that can handle about five channels of data on signal levels and one channel of information enabling identification of the signal data with terrestrial or celestial latitude and longitude.

EDITED EXTRACTS FROM CONCLUSIONS AND RECOMMENDATIONS OF GB-C STUDY ON ORBITING SPECTRUM MEASUREMENT EXPERIMENT (OSME) UNDER CONTRACT NAS W 1437

1. OSME IN MANNED SPACECRAFT:

Although a considerable number of radio communication systems have been tested operationally in orbital missions, little information is available on the magnitude of interference from man-made emissions to these missions. Occasional reports of suspected interference do occur during a failure analysis or as reported by one of the Mercury-Astronauts who heard occasional "clicks" on his receiver.

This investigation suggests that the measurement of man-made electromagnetic radiations from an orbiting aspect is feasible within the 1968-1970 technology. The significance of the data obtained from such an experiment depends entirely on the constraints imposed upon the experiment.

The significant features of the experiment are summarized as follows:

1. Measures RF (effective radiated power of 1 watt at 100 MHz to 10 kilowatt at 15 GHz) as a function of earth location with -100 dbm receiver sensitivity.

2. The astronaut will enhance the overall experiment by making decisions and performing real-time analysis of the experiment and of intentionally varied signals.

3. OSME can be integrated into a mission depending on the spacecraft and other experiments.

4. Extensive coverage of populated areas is met by orbit inclinations of 35 to 55 degrees.

5. Accumulated data may be processed and displayed by computers to the extent required by different users.

2. OSME DATA UTILIZATION:

The primary need for the experiment is based upon the concern of NASA for the interference-free operation of ground to spacecraft station communication links. A need for this type of data exists now. The rapid growth of space communication placed a third dimension on the allocation and utilization of frequencies. Measured data is generally not available and if available it is obsolete.

Secondary uses are also suggested by the continuously increasing dependence on the electromagnetic spectrum for functions vital to national and human well-being. The insidious nature of electromagnetic interference requires more data to define this environmental factor. The ultimate utilization of the data is difficult to foretell since opinions and needs are generally based upon present problems. However, the increasing awareness by the public, industry, government, and nations that the electromagnetic spectrum is a resource suggests that the data will be used for management of this resource which eventually may lead to better engineering approaches.

One objective of engineering is an optimized system which is a "best fit" with the operational environment. Therefore, the data may also be used to further the academic knowledge and study of the electromagnetic environment. "What is it," "How does it change with time and place" and also the subsequent application of this knowledge for uses such as:

- Preparing environment maps.
- Comparing actual environment with data banks such as FCC and ECAC.
- Optimizing spectrum utilization on world-wide, regional, and national basis.
- Contributing to engineering of specific communication systems.
- Locating low noise areas for siting economical satellite communication systems.
- Determining interference between spacecraft.
- Protecting and siting radio astronomy stations.

3. REQUIRED FUTURE WORK:

It is recommended that the results of this feasibility study be used to implement the experiment. This study should be further evaluated to determine the requirements of total spectrum measurement from 0.1 to 15 GHz (the objective of this study) or only specific measurement of NASA allocated frequencies. This decision should also be influenced by economics, and available payload space. The first experiment may be a single-frequency experiment or complete coverage by OSME as discussed in this report.

Certain new technology requirements in the area of wideband electronic components exist. Development studies should be contracted for if the complete spectrum coverage is desired. However, these studies are not required if the narrowband or specific frequency measurement is performed first.

The intercept probability of the different types of signals should be further evaluated. The limited effort expended as part of this study showed that the intercept probability for pulsed and scanning RF transmitter will be very low. A continued effort in this area is indicated to perform a computer assisted study for several commonly used pulsed transmitters and to use the results for optimizing receiver parameters which enhance the intercept probability.

This study suggested that an evolutionary approach to the orbital spectrum measurement be taken. The developed first generation experiment provides a broad data base which must be evaluated prior to other experiments. A unified plan should be established for a series of experiments. Some of the other experiments may be as follows:

1. Utilizing a narrow beamwidth antenna for greater sensitivity and geographical resolution.

2. Performing selected area measurement only, such as congested area spectrum utilization, and remote area measurements for satellite receiver installations.

3. Performing higher spectral resolution measurements over a narrower frequency range.

4. Performing measurements beyond 15 GHz.

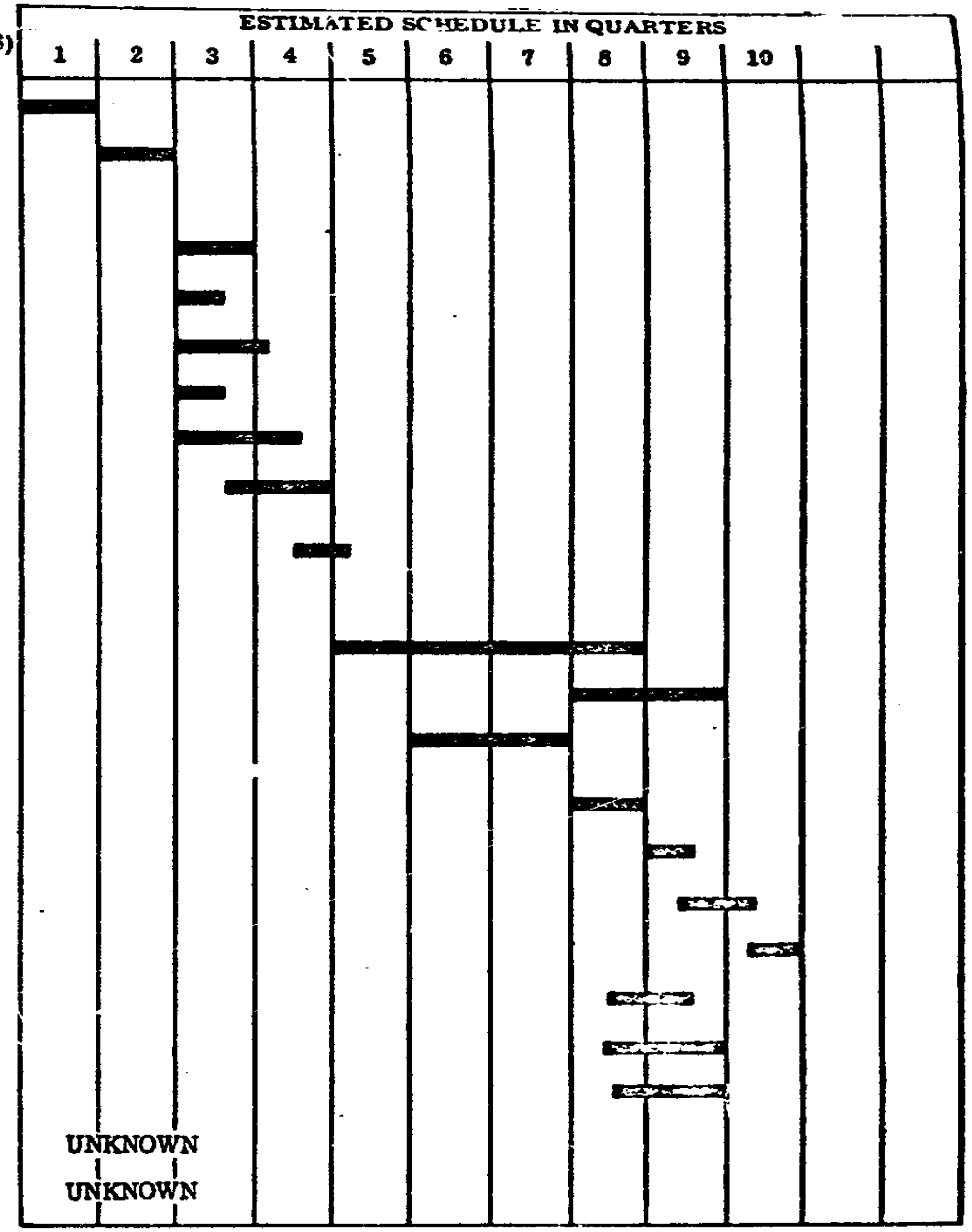
5. Performing periodic or continuous measurement as part of several missions.

6. Performing evaluation of satellite emissions in traffic congested near-space.

7. Assisting the proposed astronomy experiments aboard spacecraft which utilize directional antenna arrays directed away from earth to provide more information about radiations from earth and therefore guiding their required backlobe suppression.

Cost and schedule estimates are given in the following table:

TASKS	ESTIMATED COST ($)
1. DEFINE SYSTEM CONFIGURATION	10,000
2. PREPARE DESIGN PLAN	40,000
3. DEVELOPMENT STUDIES	
a. PRESELECTOR 0.1 - 1 GHz	30,000
b. PRESELECTOR 1 - 10 GHz	10,000
c. TWT 1 - 10 GHz	40,000
d. TWT 10 - 15 GHz	10,000
e. SOLID STATE DISPLAY	50,000
f. BREADBOARD SUBSYSTEMS	70,000
4. RE-DEFINE DESIGN PLAN	10,000
5. FABRICATE EXPERIMENT	
a. PROTOTYPE (RECEIVER)	600,000
b. 2 FLIGHT UNITS RECEIVER	600,000
c. FABRICATE ANTENNAS & HARDWARE	80,000
6. FABRICATE GSE & TEST	40,000
7. DYNAMIC EVALUATION OF PROTOTYPE	50,000
8. QUALITY ASSURANCE TESTING	200,000
9. INSTALLATION IN SPACECRAFT	10,000
10. DEVELOP SOFTWARE	60,000
11. ASTRONAUT TRAINING	30,000
12. COMPUTER PROGRAM FOR DATA	70,000
13. EXPERIMENT ASSIST	20,000
14. DATA EVALUATION	100,000
TOTAL	2,130,000



Cost and schedule estimate for OSME.

EXPERIMENT DATA SHEET

SPACE-ERECTABLE STRUCTURES

1. SPECIFIC OBJECTIVE:

Develop methods for testing and evaluating large antennas and other structures which are either self-erected or man-assembled in space.

2. GENERAL DESCRIPTION:

One phase of this experiment will be to test the quality of the high-gain tracking antenna under operating conditions in space, to develop practical methods for testing larger antennas on later flights. The basic method will be to erect a mast carrying a small probe antenna in a position on the workshop such that the pattern of radiation from the tracking antenna can be mapped without interference from radiation reflected from the spacecraft itself. The probe antenna will be fixed, and the pattern radiated by the tracking antenna will be mapped by moving the latter.

The tracking antenna pattern will be mapped at all frequencies which the antenna is equipped to radiate. The data will comprise sets of relative signal level measurements; they will be recorded in graphical form and interpreted on board the spacecraft. If EVA capabilities are available on the Intermediate workshop, plans should be made to optimize the performance of the antenna by adjusting its feed.

In general, plans for evaluating and adjusting the antenna should be aimed mostly toward developing procedures for the testing of large antennas than they are toward evaluating this particular device. Experience of this sort is vitally necessary for realistic planning of operations with large, space-erected antennas. In view of the needs that the latter devices will impose, it will be particularly valuable to perform tests at very short wavelengths, comparable to the expected deviations of the surface. Tests should also be performed with solar radiation incident from several representative directions, and, if possible, with the antenna undergoing accelerations imposed by maneuvering and tracking.

Apparatus specifically for the Antenna Test experiment will comprise a pen chart recorder for mapping the antenna pattern and a digital voltmeter for more precise measurements of output at discrete points, as well as the externally mounted probe antenna and appropriate tools if EVA work is contemplated.

3. OPERATIONAL CONSTRAINTS:

Since the experiment does not involve anything not attached to the spacecraft, the nature of the orbit will not matter. It will be desirable to execute some special maneuvers to test thermal effects; for example, keeping the antenna in the workshop's shadow for a period long enough to reach thermal equilibrium.

4. MODE OF OPERATION:

This will be entirely a manned experiment, with data interpreted on board by the crew and at least some of the procedure planned on the spot in response to the results of a prescribed initial sequence of measurements. Since detailed knowledge of the antenna's characteristics will be useful in managing the other experiments that use it, the evaluation should be scheduled early in the mission.

5. CREW SUPPORT:

The experiment will require a crew member who is familiar with antenna technology, can interpret the data, and can discuss them intelligently with personnel on the ground. Early in the mission, he will initiate and observe the mechanical erection of the tracking and probe antennas from the stowed to the operating positions. With the antenna tracking system under manual control, he will then record a prescribed set of mapping measurements on the radiation pattern, compare them with specifications, and report to the Mission Control Center.

The initial measurements will be made at the S- and X-band frequencies, and plans for the run of the experiment will be adjusted, if necessary, in response to the results. If serious anomalies are found and EVA time is available, the antenna will be adjusted to meet specifications.

As opportunity offers later in the mission, the antenna will be tested at millimeter wave frequencies and under various thermal conditions. In addition, special tests will be performed, if required, to help determine the causes of unexpected features in the data from experiments involving the antenna.

The initial proof test of the antenna will require about four hours, including interpretation of the data. Subsequent tests will be essentially "open ended," and could absorb several man-days of astronaut time in blocks of a few hours apiece.

6. SPACECRAFT SUPPORT:

To give adequate coverage of the antenna pattern without reflection problems, the probe antenna should be of the order of 100 ft. from the spacecraft. Essentially all of the weight will be in the mounting boom, which must not oscillate when the attitude control system operates. Weight of the boom and guy wires will be no more than 20 lb., and probably less.

The electronic packages used to generate and measure test signals will all come from the apparatus of other experiments. Only the output devices which present the data to the crew member will be specific to this experiment, and these will occupy about 0.5 cu. ft., weigh about 5 or 10 lb., and consume about 10 watts of power.

AN INTERFEROMETER NAVIGATION EXPERIMENT

FOR INCLUSION ON A MANNED SPACE STATION

1. BACKGROUND:

In 1966 NASA/OSSA awarded a contract to the Westinghouse Defense and Space Center to perform a study of potential navigation and traffic control space experiments which could benefit from the utilization of man. The study was under the technical management of the Marshall Space Flight Center.

The study concluded that there exists a variety of navigation/position fixing experiments which could use the large weight carrying capability of a manned spacecraft. Only one of these experiments could use man to perform useful experimentation. This is a satellite-borne interferometer.

2. EXPERIMENT DESCRIPTION:

The proposed experiment will consist of two mutually perpendicular interferometer antennas located at the ends of booms of varying lengths, from 50 to 100 feet.

The boom length will depend on the radio frequency employed. The astronaut can observe the boom deployment, photograph boom fluctuation, vary the boom length, and change interferometer antennas. Phase angle measurements could be measured at the spacecraft and compared with data received at the ground. The astronaut would monitor the equipment and make appropriate equipment modifications.

The experiment should be conducted at a number of radio frequencies to obtain data on interferometer navigation accuracy as a function of frequency. Experimentation should be made at L-band (1600 MHz) and at C-band (4,000 and 5,000 MHz). These are assigned frequencies for aeronautical navigation purposes.

As a part of such an experimental program, NASA/OSSA will arrange with appropriate aircraft and ship organizations to participate in this navigation experiment.

3. COST AND SCHEDULE ESTIMATES

The schedule is based on the availability of a spacecraft to carry the experiment in FY-1978. Costs will change as the launch date is varied:

FY-72	73	74	75	76	77	78	79
0.3	1.3	2.4	2.8	2.4	2.0	0.9	0.2

Feasibility studies and preliminary experiment definition will be conducted in FY-72-74 ($4 M) Phase A and B.

Detail design hardware development and experiment integration will be conducted in FY-75-78 ($7.5 M) Phase C and D).

Experiment Data Analysis will be performed in FY-78 and 79 at a cost of $0.8 M.

Total experiment cost $12.3 M.

This experiment is considered a Level III program in Navigation and Traff[illegible] Control.

EVOLUTIONARY PLAN FOR EARTH RESOURCES - METEOROLOGY
FIRST WORKSHOP (1970-72) THROUGH FOLLOW-ON WORKSHOP (POST-1975)

	YEARLY	70	71	72	73	74	75	76
FIRST WORKSHOP 1970-72	S100, METRIC CAMERA	B - C -						
	S101, MULTIBAND PHOTOGRAPHY	C -						
	S102, DUAL-CHANNEL SCANNER/IMAGER	C -						
	S103, SHORT WAVELENGTH IR SPECTROMETER	A - B - C -	D					
	S075, MICROWAVE RADIOMETER	C -						
	S049, IR INTERFEROMETER	A - B - C -						
	S043, IR SPECTROMETER	A - B - C -						
INTERMEDIATE WORKSHOP 1973-1975	ADVANCED METRIC CAMERA		A B					
	ADVANCED MULTISPECTRAL CAMERA		A B					
	MULTICHANNEL SCANNER/IMAGER							
	RADAR ALTIMETER/SCATTEROMETER			C				
	MICROWAVE RADIOMETERS AND IMAGERS	A	B					
	RADAR IMAGER							
	ABSORPTION SPECTROMETER				D			
	ADVANCED SHORT-WAVE IR SPECTROMETER		A	B C				
	IR TEMPERATURE SOUNDER							
	POLARIZATION MEASUREMENT IN THE VISIBLE							
	STELLAR REFRACTION DENSITY	A	B	C				
	ATMOSPHERIC DENSITY SENSING							
	UHF SFERICS DETECTION							
FOLLOW-ON WORKSHOP POST - 1975	ADVANCED METRIC CAMERA							
	ADVANCED MULTISPECTRAL CAMERA							
	MULTICHANNEL SCANNER/IMAGER							
	RADAR, MULTI-FREQUENCY, DUAL POLAR				A			
	RADAR ALTIMETER - SCATTEROMETER					B		
	MICROWAVE IMAGER, MULTI-FREQUENCY						C	
	MICROWAVE RADIOMETER, MULTI-FREQUENCY							
	ADVANCED ABSORPTION SPECTROMETER							
	AND IMAGER		A		B			D
	UV LUMINESCENCE SPECTROMETER		A		B			
	AND IMAGER		A		B			
	LASER ALTIMETER	A	B	C				
	LONG WAVELENGTH SPECTROMETER	A	B	C				
	ADVANCED IR SOUNDER				A	B	C	
	ADVANCED MICROWAVE SOUNDER		A		B	C		
	ADVANCED RADIO OCCULTATION	A	B	C				
	RAMAN SCATTERING	A	B	C				

LEGEND: DEFINITION - A
DESIGN - B
DEVELOP - C
FLIGHT - D

EVOLUTIONARY PLAN FOR COMMUNICATIONS